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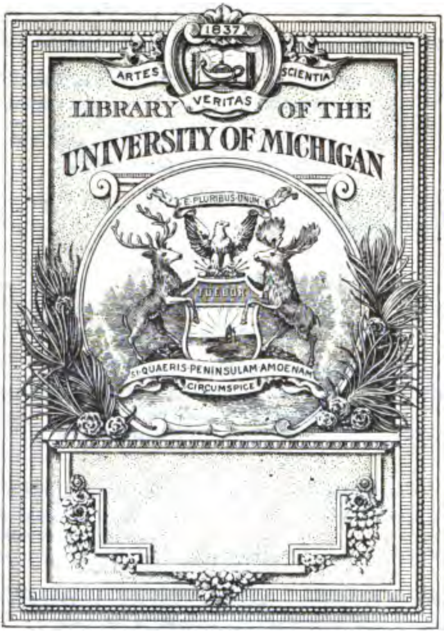

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COMPRISING

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Illustrated by an Atlas

CONTAINING 235 WOOD ENGRAVINGS OF MINING TOOLS, DRAWN TO SCALE.

BY

WILLIAM MORGANS,

LECTURER ON MINING AT THE BRISTOL SCHOOL OF MINES.

Capio Lumen

LONDON:
LOCKWOOD & CO., 7, STATIONERS' HALL COURT,
LUDGATE HILL.
1871.

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PREFACE.

ONE of the striking features of the Art of Mining, in its wide application, is the variety which characterizes the tools used for prosecuting it. This variety may be to some extent the result of prejudices which establish local custom; but in the main it is the fruit of skilful design, or selection, for advantageously accomplishing the sundry details of mining operations.

The subject in general is one of interest and importance to those who aim at promoting the prosperity of mining, since, for the successful prosecution of that industry, so much depends upon the adaptability and quality of the tools used. It is consequently requisite that the principles which regulate their efficiency should be thoroughly understood, and as several mining tools are required for work of an exceptional nature, it is desirable to have special acquaint-

ance with some points, as touching both principles and practice, in relation to those tools in particular.

It has been endeavoured to make the following pages of some service to mine managers, viewers, or captains, and overmen, whose knowledge of the quality, durability, manufacture, and selection of tools is often appealed to, and who, consequently, require to be familiar with the practical bearings of the subject.

The affording of information to mining students has also been aimed at. For their advantage the principles of operation of some of the tools have been noticed, with additional points, which otherwise would not have been introduced. It is hoped, however, that those of their number who intend to successfully direct mining operations, will be prompted by the perusal of these pages to seek possession of an acquaintance with the actual *use* of, at least, the *ordinary* mining tools. To such individuals the advantage of experience thereby gained cannot be overrated, and they should constantly remember that when the time arrives for them to take charge of the execution of work, they ought to be able to *bring to bear* the requisite practical knowledge,

and not to be entering upon the *acquirement* of it.*

Another intention has been that of affording English superintendents of foreign mines such particulars, derived from practice, as may be useful to them when engaged in the discharge of functions demanding their close acquaintance with details which, in this country, where manufacturing industry and skilled labour are always close at hand, may be regarded as insignificant and unnecessary.

With the hope that these pages will be read by working miners, and artisans concerned in the furnishing of mining tools, it has been attempted to treat the subject in a way calculated to interest and inform them upon numerous points. The writer is proud to acknowledge that much of the information which has served him well in daily practice has been communicated to him by men of these vocations, amongst whom prevails a high degree of natural intelligence, which is often concealed by modest reserve.

* Frequently, disappointments in mining enterprises are witnessed at home and abroad, through those who have control of the works labouring under the drawback of a training —if any at all—in which *actual practice* in mining has been quite neglectod.

In cases of the most common tools, data relating to the weights, costs, and prices have, in several instances, been given, as nearly as it has been found possible to strike the average ruling in this country. Although these figures may slightly fluctuate in any particular neighbourhood, and may vary somewhat in different districts, such details as are supplied will often be acceptable as a guide in agreeing for, purchasing, and valuing tools.

The writer is persuaded that a more general diffusion of knowledge regarding the special forms of mining tools used for particular work, in different districts and countries, must be advantageous. Consequently, various tools more or less peculiar to different localities, and also some foreign tools, have been illustrated. Instances are occasionally to be seen of miners working under unfavourable circumstances through being uninformed regarding tools used in a remote district.

The illustrations—drawn to scale—may be found convenient to some for reference, when requiring an insight into the character of details belonging to our subject, which, amongst mining and manufacturing circles, and in engineering

publications, are often alluded to in technical language.

The foregoing remarks summarize the purport of this little book. It has been written in the midst of busy occupation in mining and mechanical pursuits—a circumstance which, almost as a natural consequence, has added to its imperfections.

Simple as the subject appears, it was adopted because the need of some work devoted to it has been long and often expressed. Should this publication in a small measure tend to promote the miner's important calling, its production will be significantly honoured.

Any suggestions or additional information will be highly esteemed by the writer.

BRISTOL SCHOOL OF MINES,
June, 1871.

INTRODUCTION.

In noticing some points pertaining to *iron* and *steel*—which have become indispensable in the manufacture of most of the tools and implements now employed in the industrial arts—it will neither be necessary to enumerate the many different kinds of iron ores met with, nor to consider the various systems pursued for winning or working them. Many of our readers will be more or less acquainted with the processes by which iron is reduced from its ores and manufactured into a saleable product. Reference will be made to some of these processes, but only so far as partly to account for the differences between good and bad iron and steel; and, further, to explain briefly some chemical and other facts to such readers as may not have acquired much technical training.

The purest state in which the metal iron can be generally obtained is that known as *wrought-*

B

iron. Absolutely pure iron is a chemical curiosity. The best bar-iron has traces of other elements, some chemically combined, and others mechanically alloyed with it; but they appear to have no very positive influence upon the quality of the iron until their quantities become more appreciable.

Chemical analyses have proved that, almost invariably, red-short iron contains in some form sulphur, and that cold-short iron contains phosphorus; hence, when iron is tender and weak at a red heat, or when cold, the cause is attributed to sulphur in the former case, and to phosphorus in the latter. Iron derived from the ores of some districts is noted for red-shortness; that from the ores of other districts for cold-shortness. Some ores give iron which is both red-short and cold-short. Naturally, those ores which are freest from sulphur, phosphorus, and other deleterious elements, yield pig-iron most suitable for the production of best bar-iron. The smelter reduces and separates metallic iron from the ores by *slagging* or scorifying the accompanying earths, metals, &c.; and during this operation it is his duty to prevent, as far as possible, the combination of any injurious element with the iron obtained. This is partially, or wholly, accomplished by introducing to the smelting furnace,

simultaneously with the ores and fuel, such sub stances—either lime, clay shale, sandstone, or any mixture of some of these, according to the composition of the ores—as shall *flux* the earths and accompanying injurious substances in the ores, and form liquid slags or cinders, which, through being lighter, easily separate from and float upon the surface of the metallic iron. In other words, the smelter brings into intimate contact with the ores such substances as, at the high temperature produced in the furnace, have greater chemical affinity for, and offer greater attraction to, the earths and deleterious elements than is possessed by the molten metallic iron.

Injurious elements, especially sulphur, sometimes abound in the *fuel*, and they often occur in the *fluxing material* itself. If they are very abundant in any of the material which the smelter has to use, it is in practice impossible for him to prevent the combination of some of them with the pig-iron. It then devolves either upon the puddler, or refiner, to eliminate, besides the carbon—to be spoken of further on—the greater amount of the impurities from the pig-iron by his process. The result is dependent not entirely upon the skill of the workman, but more generally upon the costliness, in labour and loss of material, of the process resorted to.

A fair amount of loss in weight—according to the composition of the pig-iron—during the refining, or puddling, process, caused by forming some of the iron into cinder to attract and carry off the injurious substances, will contribute to producing good bar-iron; and severe pressure, as in rolling, or abundant percussion, as in hammering, will extrude most of the cinder suspended in the masses of iron which leave the puddling furnace, or refinery, and improve the iron to that extent. Cheaply-made iron is not submitted to severe mechanical treatment to expel the cinder (some iron being even too weak and bad to stand it), because the latter sells as bar-iron at a higher rate than as cinder, and for the cheap production of iron the puddler, or refiner, is expected to bring out from his furnace a larger proportion of wrought-iron to the quantity of pig-iron charged, than when working for better quality.

A bar of very best hammered Yorkshire iron, one inch square, will suspend a load of 28 tons before it breaks; and a cubic inch of such bar-iron will weigh, as nearly as possible, $7\frac{3}{4}$ times more than a cubic inch of pure water—both iron and water being at the ordinary temperature of 60° Fah. Common qualities of iron, especially those which have not undergone sufficient mechanical treatment during manufacture to expel the in-

terposed cinder and compact the iron, and other sorts having injurious elements in combination, will break with a load of from 20 to 22 tons per square inch; and a cubic inch of such quality will not generally weigh more than $7\frac{1}{2}$ times the same volume or bulk of water. A cubic inch of forge or mill cinder does not weigh more than from $3\frac{3}{4}$ to 4 times the weight of the same volume of water; and the presence of some such cinder, improperly occupying the place of iron in bars, reduces the specific gravity of the latter, besides impairing their strength. The very best bar-iron contains a little cinder, some of which may be seen to "sweat" out when at a good heat in a clear fire.

One of the most useful and valuable properties of wrought-iron is its capability of *welding* when at a high temperature. In a good weld the union is so complete and perfect, that upon the application of strain there is no greater tendency to rupture at the weld than elsewhere—that is, supposing the cross section at the weld to be of exactly the same area as at other points in the bar.

It is essential for welding that the surfaces brought into contact should be free from scale. Iron, highly heated, scales very rapidly when in contact with air. Scale is formed in a smith's

fire, and the more rapidly when there is only a thin layer of fuel between the article being heated and the twyere, because some of the blast in an almost "raw" state touches the article; or, in other words, the fuel does not abstract all the oxygen from the blast before the latter comes into contact with the article, and the remaining oxygen then scales it.*

Iron scale is simply iron and oxygen combined, and commonly in the proportion of 7 of the former to 3 of the latter by weight, so that 10lbs. of scale contain 7lbs. of iron, but sometimes more.

Scale can be melted at a very high temperature, but it is not fusible at the welding heat of iron, and therefore it sticks to the *scarfed* ends prepared for a weld; and wherever it thus occurs the welding is defective, since it prevents proper contact of the two scarfs, and consequently there is no union at that particular part. Common

* Disregarding moisture and about $\frac{1}{1000}$th part of carbonic acid, common atmosphere consists by volume of 79 parts of nitrogen to 21 parts of oxygen; by weight of 77 parts of nitrogen to 23 parts of oxygen. It is the chemical combination of the oxygen of the air with the fuel that burns the latter. Nearly all the coal consumed in a fire-grate goes up the chimney in the form of carbonic acid gas, which, when pure, is invisible. Each pound of carbon—fuel—requires $2\frac{2}{3}$lbs. of oxygen for its perfect combustion, and this quantity of oxygen is contained in 11·594lbs. of air, which, at ordinary temperature and pressure, measure 143·6$\dot{2}$ cubic feet.

sand is more infusible than iron scale, but in the proportion of about 3 of sand, by weight, to $7\frac{3}{4}$ of scale, a compound is produced which melts at about the temperature of 1,600° of Fah.—the welding heat of wrought-iron approximating 2,700° Fah.

This singular melting property of mixed sand and scale—similarly possessed by many other compounds—is of the highest value for welding iron. The addition of a little sand to the scarfs while they are being heated not only dissolves the scale invariably formed in a smith's fire, but the resulting fluid compound—chiefly tribasic silicate of iron—forms a coating to the scarfs largely preventing their further oxidation by the blast. When the two scarfs are butted together on the anvil, the sledge blows expel any liquid slag with the greatest ease, and thus clean unscaled surfaces of iron are brought into contact at a welding heat, and united before the surrounding air has time to effect any scaling.

Workmen should be careful to form scarfs full in the middle, rather than dished, as is often done. If so hollowed out, the two scarfs, upon being brought together, resemble the cups of a closed bullet-mould, and, being welded at the edges first, sometimes enclose a little cinder or slag, which weakens the weld as much as the presence

of scale. If, after welding the edges, the hammering is sufficient to force out any enclosed slag, the iron must again open at the weld, or some other place, to admit of this. On the other hand, when both scarfs are full in the middle, there they first unite, and the welding proceeds towards the edges—all the slag being easily forced away as the welding extends.

It is proper to remark that, strictly speaking, iron scale and sand do not chemically combine. There are three well-known oxides of iron of the following percentage composition:—

	Per cent.		Per cent.
Red oxide, or sesquioxide of iron,* contains iron	70·00	and oxygen	30·00
Black oxide, or magnetic oxide . .	72·41	„	27·59
Protoxide of iron	77·77	„	22·23

Protoxide of iron is difficult to obtain in a separate form, and if exposed to the atmosphere, it is instantly changed into sesquioxide by the absorption of more oxygen from the air; but almost every *combination* of oxidized iron with other substances occurs with the iron in the *protoxide* form; and if any other higher form of oxide is presented for combination, it is first deoxidized, or reduced to protoxide, before the combination is effected. Iron scale consists of

* Common rust is sesquioxide in combination with water. It is known as hydrated brown oxide.

layers of mixtures of each of the above oxides. The outermost layer contains most oxygen, and is nearly pure sesquioxide. The middle layer is nearly pure magnetic oxide—scale being strongly magnetic, as may be shown with any common horseshoe magnet—and the innermost layer, next the iron, is a mixture of magnetic oxide and protoxide. Sand, chemically known as silica, will combine with iron in the protoxide state only. At a high heat, sand in admixture with red oxide will reduce the latter to protoxide—by driving off some of the oxygen—and then combine with the protoxide to form slag. This occurs in the process of welding iron. The reduction of scale to protoxide is greatly assisted, too, by the presence of the fuel, which is nearly all carbon, and which has a great affinity for oxygen at a high temperature.

It may be useful to observe here that, in the absence of sand, a welding slag may be obtained by dipping the heated scarf into finely-powdered limestone, or unslaked lime. This is one of the exceptional cases in which the sesquioxide combines with another substance in metallurgical operations. In the proportions of 8 of sesquioxide of iron to 5 of limestone, or to $2\frac{4}{5}$ of unslaked lime, a fusible slag is formed experimentally. The fact that scale and lime will form such

a slag is occasionally taken advantage of by smiths.

The appearance of the fracture of wrought-iron varies with the mode and rapidity of its occurrence. A good bar of iron slightly nicked with chisel or clift, and then slowly bent to and fro until it breaks, displays a fracture full of fine, clean, bright, silky fibres, of some shade of dark grey colour. The same bar nicked deeper, with the nicked part placed between supports two or three inches apart, and there smartly struck with one or more good blows, will break short off, and show a crystalline fracture of a colour very near that of silver. Frequently in the piling up of pieces of puddled bar for the succeeding process of rolling out into finished bars, pieces of inferior quality, yielded by pig-iron derived from cheap ores contaminated with phosphorus or any other injurious element, are built into the middle of the pile. The presence of any cold-short iron from phosphatic ores, thus introduced, may be discerned in the fracture of a bar which has been broken by a dead pull, as having a light and bright crystalline short-broken appearance, surrounded, perhaps, with moderately good fibre. As the strains producing such a fracture act almost uniformly upon the molecules of iron, it is clear that it must be composed of different qualities to show the dis-

similarity of fracture. A crystalline fracture may be induced in the *middle* of a uniformly good bar by a to-and-fro breaking movement, as at that place—the neutral axis—no tensional strain from the bending, which develops fibre, has acted upon the iron, and the fracture of the central part being sudden, is therefore similar to that produced by a smart transverse blow.

Similar crystalline patches in a fibrous fracture may result from insufficient working—incomplete decarburization—in either the puddling furnace, or refinery. Such is known as *raw* iron by forge workmen. Its condition may range from that of mild puddled steel up to that of cast-iron.

The appearance of the fracture of iron, wrought or cast, is by no means a perfectly reliable index to its quality. Very indifferent wrought-iron sometimes shows good fibre. As a rule, the finer the crystals and fibres are, the better the quality. Sometimes very strong hammered charcoal-refined iron, when smartly broken, shows a very coarse crystalline fracture. Good bars generally have a clean smooth skin, with their edges full and sharp, and free from skin cracks. A similarly clean and smooth appearance can be imparted to inferior bars by passing them through the last and finishing groove of the rolls at a low heat—an arrangement being at the same time provided

for carefully removing any scale adhering to the groove, that it may not be pressed into the skin of the bar at the next revolution.

The quality of bar-iron is best determined by a direct-pull testing machine, supplemented by a smith's trial of subjecting it to bending, and to punching near the edge, both while in a hot and cold state, and also to a good heat to determine its welding capability.

Good bar-iron is inclined to brittleness when exposed to cold during frosty weather. Chains and bars often then snap suddenly when struck. If a bar requires slight bending during very cold weather, it should be first slightly warmed.

Long-continued vibration, or percussion, will resolve fibrous iron into crystalline. This is frequently seen in broken railway-waggon axles.

Steel occupies a chemical position between wrought and cast iron. Wrought-iron holds only the slightest quantity of the element carbon. Coal, soot, plumbago, and the diamond are each carbon in a less or more pure form. In iron, carbon can exist simply suspended or *uncombined*, so that it is disseminated in distinct particles or flakes through the iron, although these particles may be too fine to be visible; but in some descriptions of iron they are easily perceived. It occurs

in this way in, and gives distinctive properties to, dark grey pig-iron, and from a fresh fracture of such pig-iron it can occasionally be picked out with a penknife in the form of scales of graphite or plumbago. Carbon can also exist in iron in a chemically *combined* state, in which case the physical features of the carbon are entirely lost, as in steel, and most kinds of white pig-iron, some of the properties of which differ widely from those of grey pig-iron, and still more widely from those of pure iron, or pure carbon. We have already seen that by the chemical combination of iron scale and sand, induced by heat, a compound is produced, having some important qualities different from those of either of the substances of which it is formed. Pig-iron holds an average of from 3 to 5 per cent. of carbon. In dark grey pig-iron it exists mainly in flakes of graphite, but yet with some little in combination. Such cast-iron is soft, is not very strong, can be readily chipped and filed, is only very slightly elastic, and breaks with a dull thud or leaden sound when thrown down smartly across any other piece of iron. Light grey and mottled pig-irons have the carbon partly free and partly combined. They are harder than dark grey under the chisel and file, are both stronger and tougher, break with a clearer sound, melt at a lower

temperature, and shrink more during cooling. In white iron the carbon is nearly all in combination. It is much harder than the greyer sorts, and sometimes cannot be chipped or filed. It breaks with a clear bell-like sound when thrown, is very brittle, and therefore weak for most purposes, and is used only in such castings as require hardness without strength.

Pig or cast iron cannot be welded, but is quite brittle under the hammer at a high red heat. The presence of as little as .2 per cent. of carbon deprives cast-iron of the property possessed by wrought-iron, of becoming plastic and weldable through a considerable range of temperature before arriving at the melting point.

Steel contains from ½ to 2 per cent. of carbon. When the quantity of carbon is small, the steel is termed "mild;" and, seeing that it then differs from wrought-iron only in the matter of about ½ per cent. of carbon, it naturally partakes largely of the properties of wrought-iron. Like it, it is readily weldable, and only melts at a high temperature, but is stronger, tougher, and more elastic than wrought-iron.

As the amount of carbon in steel increases, both its melting point and weldability decrease. Steel with 1½ per cent. of carbon very decidedly partakes of the properties of cast-iron, and if then

capable of welding, it is so at a very much lower heat than wrought-iron.

Of the several methods of manufacturing steel, we will, in a few words, glance at only two, viz., Bessemer's, and the Sheffield cementation process.

The *Bessemer* process begins operations upon pig-iron containing 4 or 5 per cent. of carbon. From this, steel, containing any desired quantity —say from ½ to 1½ per cent.—of carbon, is obtained by blowing common air *upwards* through the pig-iron in a molten state, contained in a converting vessel, suitably lined with some very refractory material, and having a perforated fire-brick bottom through which the blast is introduced. The converting vessel is filled with molten iron to a dêpth of about two feet, and as a column of iron that height exerts a pressure on the bottom of the vessel of about 6lbs. per square inch, the pressure of the inflowing blast must necessarily be above that, to prevent the iron from running down through the perforated fire-brick twyere. To debar the possibility of this, and to hasten the process, blast is commonly supplied at a pressure of from 15lbs. to 20lbs. per square inch. The molten pig-iron thus operated upon is run from a cupola, or air-furnace, into the converter, the blast being, of course, turned on before the iron comes into the vessel.

Now grey cast-iron often contains as much as 2 per cent. of an element termed silicon, and the presence of nearly this amount is requisite for the success of the Bessemer process. Experiments have shown that the blast first attacks the silicon, and converts it into silica—a substance identical with common sand—and so much heat is developed by this chemical change as to raise the temperature of the mass very considerably—a favourable condition for the continuance of the conversion. The silica produced incorporates itself with any cinder previously existing in the pig-iron, and further combines with any oxidized iron, resulting from the blowing, to form cinder. The cinder floats on the surface of the metal, and much of it is projected through the neck of the converter by the violent boiling of the mass.

As soon as nearly the whole of the silicon is oxidized into silica, the blast begins to attack the carbon, to combine with and remove it, in the form of carbonic oxide gas, which burns with a pale blue flame at the mouth of the converter, and engenders an intense heat. Although upon first thought it might scarcely have been expected, the heat developed during the combination of the silicon and carbon of the iron with the oxygen contained in the blast is something astonishing.

In the early days of the process, Mr. Bessemer used to stop the blowing when so much of the carbon had been consumed as would leave the desired amount of that element in the fluid mass, which would then be properly called steel. It was, however, found impracticable to stop at the desired point with any degree of accuracy, and so, instead of attempting this, the whole of the carbon was burnt out, and a plan of Mr. Mushet's adopted—that of adding to the decarburized mass a known weight of molten pig-iron, containing a known weight of carbon. Thus, if the vessel contained 4 tons of decarburized iron, which it was desired to form into steel having 1 per cent. of carbon, it would be necessary to add about 90lbs. of carbon—about 22½lbs. to the ton—to effect that object. In a ton of iron known to contain 5 per cent. of carbon, the total of carbon amounts to 112lbs. Therefore, by melting, and adding a ton of such iron to the 4 tons in the converter, the whole mass of 5 tons would be saturated with 112lbs. of carbon—one hundredth of the whole, equal to about 22½lbs. of carbon to the ton of metal—thus giving steel with 1 per cent. of carbon, as desired. It is seldom, in practice, that so much as 1 per cent. of carbon is added. Frequently it happens that by insuring the total removal of the carbon the iron gets

overblown, resulting in the oxidation of some of the iron itself after the carbon is all gone. By continuing the blowing, the whole of the iron could be burnt away in this manner. Any free oxide of iron thus formed, and floating in the mass, has to be removed, or its presence in the pores of the cast-steel would greatly damage its tenacity. The removal of such oxide is very simply and beautifully effected thus:—The pig-iron having a known percentage of carbon, and which is added to the decarburized iron in the converter, has also from 5 to 10 per cent. of the metal manganese alloyed with it. Manganese, having a greater affinity for oxygen than is possessed by iron, attacks the oxide of iron mingled in the mass, and frees the iron by combining with its oxygen. The oxide of manganese which is thereby formed readily rises through the mass and mixes with the slag, which it renders still more fusible and liquid by its presence. Pig-iron alloyed with sufficient manganese for the purpose just referred to is most commonly produced in Germany, and is known as spiegeleisen. As soon as spiegeleisen has been added to the converter, the mass is run into ingots and cooled. After examination, the ingots are heated, hammered, and rolled into bars.

Unfortunately, blowing air through pig-iron

does not remove either sulphur or phosphorus, and the Bessemer process is so far restricted to the use of pig-iron containing only traces of those elements. During the blowing, there is a certain loss of weight in the charge by oxidation and removal of silicon, carbon, and some iron; but as sulphur and phosphorus are not attacked or reduced in quantity, the mass, at the termination of the blowing, contains a larger percentage of those elements than at the commencement.

The other process of producing steel which will be noticed is that very extensively followed in this country, and known as *cementation*. It is far less direct than Bessemer's original, and much less expeditious than his modified, process. The cementing process starts with bars of good wrought-iron, derived, almost invariably, by complete decarburization of pig-iron. They are then saturated with from $\frac{1}{2}$ to $1\frac{1}{2}$ per cent. of carbon to form them into steel, the operation being simply that of putting back a portion of an element which once before existed in the iron. This is effected by placing the bars in layers alternately with layers of ground charcoal in a rectangular "pot," or walled crucible, capable of holding from ten to twenty tons of bars. Each bar is completely surrounded with a layer of charcoal about half an inch thick, space being allowed for expansion.

The "pot" is constructed over a fire-place, and is surrounded with flues. When filled with the layers, the top is closed with a thick plastering of sand and clay, or any substance suitable for forming a compact and gas-tight covering at a high temperature. Fire is next kindled under the pot, and the heat brought up to about 2,000° Fah., the melting point of copper, in the course of from twenty-four to forty-eight hours. This heat is continued as equably as possible for from six to nine days, the time being dependent upon the thickness of the bars and the amount of carbon it is desired to impart to them. If for certain bars six days would be deemed sufficient to make *spring*-steel, about seven days would be required for the production of that for *shear*, and eight days for that for *cast* steel. After conversion, each 100lbs. of bars has increased to from 100½ to 101lbs., according to the degree of carburization. If the process were prolonged, highly-carburized *cast-iron* would be produced. The carburization is by no means uniform in the whole of the bars, and there is often much difference at different points in the same bar. The bars situated in the hottest positions absorb most carbon. After treatment in the pot, the bars are covered with blisters, and are known as *blister*-steel.

The cause of the blistering is the subject of two or three scientific theories. It is believed to occur only where a little slag exists in the pores of the bars; and as its presence weakens the tenacity at those points, the heat causes a separation and blister by expansion, assisted by pressure from gas generated through chemical reaction between the advancing carbon and the impounded cinder. It would be expected that in the best and most uniformly worked iron the unexpressed cinder would be most uniformly distributed, and so cause a regular arrangement of small blisters over the steel. The best iron does yield such steel, whereas inferior bars, after conversion, display large and small blisters of very irregular occurrence.*

* Case-hardening wrought-iron is effected by the application of the cementation process during a short time only. Case-hardened turned and fitted pieces of iron are frequently used in the gearing of engines and machines, and for other purposes. Axles and journals are sometimes thus superficially hardened, as are also screw-bolt nuts which have to be frequently moved with a spanner. This occasionally very serviceable process is conducted in the following manner:—In a wrought-iron box of suitable size, made of sheet-iron or boiler-plate, is laid a layer of dried parings of leather, horns, or hoofs, to nearly an inch in depth. If thought proper, these substances may be previously charred enough to admit of their being crumbled into coarse dust for use in layers. Upon the bottom layer are placed some of the articles to be hardened, with not less than quarter-inch spaces between them. These spaces are then carefully filled with the dried parings or charred powder, and the iron articles are overlaid with not less than one-quarter inch of the same

In *cast*-steel the carbon is more uniformly distributed than in blister-steel. It is manufac-

carburizing material. Alternate layers of iron articles and parings are arranged, finishing with a top layer of parings of not much less than an inch in thickness, as at the bottom, ends, and sides of the box. A flanged cover is placed over, or a plain cover is dropped into a rabbet in, the top of the box, and the joint well luted with fireclay, to exclude air as perfectly as possible. The box is then placed in any heating furnace or fire at hand, gradually raised to a good red heat, and steadily maintained at that heat for from half to three or four hours, according to depth to which it is required to carburize. Two hours will carburize some qualities of iron to a depth of nearly one-sixteenth of an inch. Upon withdrawal from the fire, the box may be opened and the articles at once dipped in cold water, when they will be hardened to the depth to which they are carburized; or the box may be covered with ashes and allowed to cool slowly, after which the articles must be heated and quenched, as in ordinary hardening. Cast-iron boxes can be used for the case-hardening process, but require more care in handling. The case, while in the fire, being always hotter than its contents, allows for free expansion of the latter; but if allowed to remain in the case until cold, the case, from its earlier cooling, contracts first, and is thus capable of throwing enough of strain upon delicate articles within to distort them. To prevent bending in any of the articles, a heat sufficient to soften them should be avoided, otherwise the unequal pressure from the top layers will alter the form of the bottom ones. The leather and hoof parings, &c., used in the above process, besides being carbonaceous, are nitrogenous. Some chemists assert that nitrogen is essential to the conversion of steel, and, further, that it exists in all steel. Others dispute both these statements, especially the latter. The presence of nitrogen may have a catalytic influence upon the carburizing process. A convenient and ready means of case-hardening to a slight depth, for polishing, or moderate wearing, purposes, is simply to sprinkle upon the red-hot article powdered yellow prussiate of potash (ferrocyanide of potassium). This substance, during the few seconds the requisite temperature exists, effects carbu-

tured by cutting up the latter into small pieces, and melting them in crucibles, then casting into ingots, and afterwards tilting the ingots into bars. The melting is generally conducted in small draught coke furnaces, similar to those used for melting brass in pots. It being necessary to exclude the air, the pots are closed with covers. The heat required is manifestly above that required for welding cast-steel. From this process, it is evident that simply *heating* steel to a high temperature, even above its melting-point, does not injure it if *air is excluded*. Air present

rization enough to give a hardened surface upon quenching in water. By returning the article after sprinkling to a quiet fire, and re-sprinkling once or twice before quenching, hardness to a greater depth may be obtained. Yellow prussiate of potash is prepared from skins, horns, woollen rags, &c., and consists percentically very nearly of—potassium, 37; carbon, 17; nitrogen, 20; iron, 13¼; water of crystallization, 12¾. The latter is driven off upon the application of heat.

Malleable cast-iron, the introduction of which is daily progressing, is prepared by cementation, the object being to *withdraw* instead of to *introduce* carbon. In most foundries the details of the process are kept strictly secret, but the points refer chiefly to the kind of pig-iron used. After objects are cast in the usual way, they are embedded in red iron ore—sesquioxide of iron—then raised to a bright heat, bordering on fusion, and kept at that temperature for from two to four days, according to the size of the articles and depth to which it is needful to decarburize them. The red oxide of iron at this heat parts with some of its oxygen, which combines, through stronger affinity, with the carbon of the casting, by that means forming a gas which escapes. The iron ore is reduced to the state of magnetic oxide, and possibly lower. Cast-iron so treated is toughened, and afforded malleability when cold.

in a smith's forge instantly acts upon hot steel, by removing some of its carbon and oxidizing or burning some of its iron—both effects injuring the steel if they occur beyond a very small extent. For this reason a difference exists between the processes of welding steel and iron. While heating wrought-iron the scarfs are allowed to scale to a slight extent, in order that a protecting cinder may be formed by the scale and sand when the latter is applied. During the heating of steel for welding, it is sought to prevent oxidation altogether. This is done by dipping the steel, at a dark red heat, into powdered borax, which of itself forms a liquid glaze at a low temperature. By heating in a clear fire, and frequently adding borax, scaling of the steel may be entirely prevented, seeing that the borax glaze protects it exactly as the fusible cinder protects wrought-iron.

Shear-steel is obtained by cutting blister-steel into lengths, then piling them into faggots, and afterwards getting them up to a welding heat, so that they may be drawn out into bars under a tilt-hammer. The product is known as *single-shear* steel. When single-shear bars are in like manner cut up, faggoted, and drawn out, the product is called *double-shear* steel. During the shear-steel process the percentage of carbon is

somewhat reduced in course of heating and hammering; but it is clear that shear-steel has its carbon more uniformly disposed than blister-steel.

The presence of the carbon in steel very singularly renders it capable of being *hardened* to a very high degree; and, whether in a soft or hard state, steel is materially stronger than the pig, or wrought iron, from which it was made. The reason why heated steel becomes hardened by a sudden and great reduction of temperature is not perfectly understood. Singularly enough, it becomes slightly increased in volume during the process, so that a cubic inch of soft steel measures rather more than that size after it has been hardened: consequently, for equal bulks, soft is heavier than hardened steel. In usual practice, heated steel is hardened by sudden quenching in a fluid. Water, oil, and mercury are the fluids most commonly used. Neither of them is a good conductor of heat; nevertheless, they rapidly abstract heat from an immersed article by the processes of conduction and convection. When a molecule of either of these fluids touches something hotter than itself, it abstracts heat by conduction, and accordingly expands in volume. It consequently becomes lighter for *equal* volumes than the surrounding molecules, and is pressed upwards towards the surface by them. Fresh molecules

then touch and expand, and in their turn are pushed upwards by the colder and denser ones, and thus an ascending current is formed, each atom of which takes away some heat from the article immersed. For *equal* additions of temperature, water expands about two and a half times more than mercury; but, on the other hand, the same *quantity* of heat that would raise a given weight of water *one* degree, would raise the same weight of mercury *thirty* degrees; hence, for equal quantities of heat imparted to equal weights of water and mercury, the mercury expands about eleven and a half times more than the water, which results in its partaking of a much quicker motion, by which the heat is conveyed away more rapidly than in the case of water. Mercury is the most useful of all fluids for disclosing the presence of carbon by the hardening process. It will harden steel that has too small a quantity of carbon to be affected by water.

Oil is not quite such a good conductor of heat as water. A quantity of heat that would raise a given weight of water *one* degree, would raise the same weight of olive oil *three and a quarter* degrees. For *equal* increments of heat, the rate of expansion of olive and most oils is nearly double that of water. For equal *quantities* of heat imparted to equal weights of oil and water, the

oil expands five and a half times more than the water, and would thereby ascend from a heated article, by the influence of convection, much more rapidly than would result with water, and, so far, would insure quicker cooling; but as it happens that a red heat carbonizes oil, any red-hot article plunged into it is immediately coated with a little charred oil, which largely prevents further contact between the liquid and the article immersed, and thus retards the cooling process.

It must be remarked that at 212° Fah. water is vaporized, as is mercury at 660°; and since even highly-carburized steel requires a dull red heat, say 1,200°, before hardening can be effected by quenching, it follows that upon its immersion in water or mercury, either of these fluids is necessarily vaporized, and the hardening is effected in an envelope of vapour. The simple changing of state from fluid to vapour instantaneously abstracts a very large amount of heat, which becomes latent in the vapour. The vapour, being so much lighter than the fluid, in a moment rushes upwards, where it is condensed,* if covered with sufficient fluid, and is followed by succeeding

* In the case of water-hardening, if any scaling has occurred in the water by which some of the latter has necessarily been decomposed—its oxygen having gone to form the scale—the liberated hydrogen is not condensed by the overlying water, but escapes as gas.

portions of vapour—the effect being a very speedy reduction of heat in the article immersed.

The degree of hardness imparted depends upon the difference of temperature between the heated steel and the cooling medium. The greater that difference, the greater the resulting hardness; but while very hot steel quenched in very cold water is made extremely hard, the long range of cooling here involved is so violently sudden as often to fracture steel so treated, or, if not that, it induces such unequal internal strains as occasion great liability to break from percussion or sudden strains. Thin strips of steel at a strong heat can be hardened in boiling water. Highly-carburetted steel is more sensitive to hardening, and becomes harder, than mild steel containing less carbon. It requires more care than the latter, being far more liable to fly. It consequently does not bear heating so high as mild steel before quenching. In cold weather water is generally warmed to about 60° Fah. before it is used for hardening. If during cold weather anything thin is hardened in warmed water, and then quickly exposed to cold air, especially to a cold draught, the further reduction of temperature frequently causes the steel to fly, unless of mild quality.

For the sake of tenacity and toughness, the lowest possible heat requisite for producing the

desired hardness should be imparted to the steel prior to quenching, because then occurs the least range of reduction in temperature, which is attended with the least tendency to disruption within the steel. A matter of great significance is the fact that steel hardened in oil is not merely toughened, but is likewise increased in tenacity. Steel hardened in water bears less pulling strain than the same steel in a perfectly soft state. Smiths have long practised hardening screw-taps and other tools in oil for toughening them; but, until demonstrated by Mr. Kirkaldy, it was not understood that steel so hardened was much increased, but was rather believed to be decreased, in tenacity. Experimenting upon pieces of the same bar of chisel-steel, of unusually good quality, that gentleman found that one piece in a perfectly soft state broke with a pulling strain of 54 tons to the square inch of cross area; another piece, highly heated and hardened in water, with 40 tons; another piece, hardened at same heat, and tempered to "yellow," with 45 tons; another, similarly hardened, and tempered with tallow to "spring" temper, with 47 tons; another, so hardened and tempered to "blue," with 50 tons; another, highly heated and quenched in oil, required 96 tons per square inch to break it. Each piece was turned down in a lathe to about

half an inch diameter before the experiments were begun. As regards quenching in oil, it was found that the higher the steel was heated before dipping, the stronger it became. The reverse of this is true with water-hardening. That there is a wide difference, chemically and physically, between the operations of hardening in water and oil will be readily perceived. Water is composed, by weight, in round numbers, of 89 per cent. of oxygen, and 11 per cent. of hydrogen—both of these elements being gases when in a free state. Their affinity for each other when combined, as in water, is not very strong. Red-hot iron easily breaks the combination, by taking the oxygen to itself, and freeing the hydrogen as gas. When a large and highly-heated piece of iron is immersed to a shallow depth in water, it fires the liberated hydrogen gas, which may be seen burning in yellowish-blue flames on the surface of the water. With lower heats and greater depth of water, hydrogen does not take fire, but it always escapes, if unobserved, when iron is in the least degree scaled by the action of water. The oxygen seized by the iron forms the well-known scale, which, being thin, brittle, and instantly cooled, is peeled off and drops away by the later contraction of the iron. It has been observed, in the foregoing notices of the Bessemer and other

metallurgical processes, that when oxygen is brought into contact with a highly-heated mixture of iron and carbon, as ordinary pig-iron, the carbon first combines with oxygen—the affinity between these two being greater than between iron and oxygen. When hot steel is dipped in water, and decomposes the latter, the same ratio of affinity for oxygen exists between the iron and carbon forming the steel, and it is probable that the carbon is removed to a greater depth than the iron is scaled, in proportion to the greater or lesser heat of the steel. It might be expected that the sudden movement among the molecules of steel, during the rapid fall of temperature in hardening, would diminish its tenacity, and this might be somewhat promoted by a slight decarburization of its surface, if such is assumed to occur.

Now wood—which, when heated without access of air, yields charcoal, besides some liquid and gaseous products—has an average composition of —carbon, $52\frac{1}{2}$; hydrogen, $5\frac{1}{4}$; and oxygen, $42\frac{1}{4}$ per cent. Olive oil, which is similar in composition to most common oils, contains—carbon, 77; hydrogen, $13\frac{1}{2}$; and oxygen, $9\frac{1}{2}$ per cent.; and in the absence of air becomes carbonized or charred at between 600° and 700° Fah. An ordinary red heat, visible in daylight, is of about 1,000° or 1,100° Fah. in temperature, so that red-hot iron

or steel, if covered with oil, will readily char the latter. This occurs in oil-hardening. A coating of soot covers the article after the process, instead of the scale attendant upon water-hardening. This sooty covering attached to the steel being a bad conductor of heat, greatly retards the rate of cooling, and in this respect the process resembles annealing, in giving the molecules some time for equable arrangement. At a red heat carbon will *combine* with iron, or, at the same heat, will *disunite* itself from iron to combine with any element at hand, as oxygen, for which it has a greater affinity. It is possible that during the short time a red heat exists in steel immersed in oil, a slight carburization or case-hardening of the skin occurs, from the presence of sooty carbon—a process exactly the reverse of that presumed to occur by water-hardening. Regarding this point, and still more the retarded rate of cooling, a wide difference is to be expected between the effects of immersion of hot steel in oil and in water.

When numbers of any article are to be hardened, a special heating furnace is made, suitable to the size and number of the articles it is desired to have together in the furnace. As one hot article is withdrawn, a cold one is introduced, which becomes hot enough for dipping by the time its turn comes. Such articles are generally supported

above the fuel, that they may be in contact with flame only; and flame-giving coal, in small lumps, is constantly thrown on the fire by hand, and the draught regulated with a damper, to produce an abundance of smoky flame. When articles thus heated are withdrawn for quenching, they are coated with hot soot, instead of scale, and the steel suffers no damage. In furnaces for this purpose, heated by carbonic oxide gas, the admission of air for its combustion is so regulated that the gas is always in slight excess; accordingly, the oxygen of the air admitted is all appropriated by the gas, leaving none to scale the articles.

Sometimes a bath of molten lead, kept at a constant red heat, and covered with sawdust, is employed for heating articles for hardening. No scaling occurs during heating by this mode.

All hardening operations are, for the sake of judging heats, best conducted in the dark; and darkened shops are for this purpose provided in establishments where hardening is extensively practised.

Chisels, borers, &c., to be hardened are generally treated for this purpose in a smith's fire at the time they are made or repaired. It is well to have them thoroughly covered with fuel, and far enough from the twyere to prevent contact of the blast with the steel.

Several theories to account for the hardening of steel have been propounded by distinguished chemists and others. There is not compass for inserting any of them here.

The operation of *tempering* steel requires as much skill and judgment as, or even more than, hardening. The theories to account for hardening are elaborated to explain the phenomenon of tempering. One or two of them are supported by considerable probability, but not perfect proof.

It is desirable to use all tools at the lowest possible temper compatible with the performance of their work. The lower the temper, the stronger and tougher is the steel, and therefore the longer it will endure in work; but in all cases the hardness of the tool must be so much in excess of the hardness of the material operated upon, as shall remove the necessity of too frequent grinding or sharpening. It occasionally happens in rock-boring operations that tools having the utmost hardness are "blunted," from the very refractory nature of the ground, after a few blows only, although with light percussion the edges may not "fly." When a tool is to be prepared for work, it is first hardened, and then some of the surface around the cutting edge is filed, ground, or rubbed up cold to a clean and bright surface. Heat is then applied to the hardened portion, and the brightened sur-

face is carefully watched for the colours produced, which always succeed each other in regular order as the temperature increases. The order according to which they appear is as follows: pale yellow, straw yellow, golden yellow, brown, brown dappled with purple, purple, bright blue, full blue, and dark blue.

Experience has shown that for edge-tools, saws, files, &c., for specific purposes—which should always be made of steel having the most suitable percentage of carbon—certain of the above colours are particularly suitable; but the best colour and temper vary somewhat in tools for the same purposes when there is a difference in the amount of carbon in the steel from which they are made. The steel possessing most carbon must be brought to the lowest temper.

Brightened surfaces of iron, when heated, acquire colours in the same manner and order as steel, but not so distinctly, and a higher temperature is required to produce any given colour. When iron and hardened steel, both brightened, are similarly heated together, the iron will have acquired only a straw colour when the steel is purple or bright blue.

Both hardening and tempering of many things, as chisels, borers, &c., are performed by a single heating. Their cutting edges are first dipped

and hardened, and then immediately filed, or ground, or rubbed bright. The heat stored up further back in such tools is sufficient to bring the edges gradually down to the colour required, whereupon further progress is arrested by instant quenching. When hardening and tempering are made two separate operations, first by completely cooling the article for hardening, and next by raising it to the necessary tempering heat, the heat for the latter object is sometimes imparted by holding the article in a flame, or on some hot substance; but when quantities are to be tempered, metallic baths are provided for heating them. Metals melt at certain constant temperatures, and mixtures of them melt at certain intermediate constant temperatures. Experiments having shown what temperatures are required to produce certain temper colours, the proper alloys are prepared, and kept just melted, so that articles dipped into them acquire the desired temper with great certainty and uniformity.

The following table shows the melting points of certain alloys, and some of the articles for which such tempering heats are employed :—

Lead	Tin.	Melting point, Fah.	Colour.	Suitable for tempering
		Dg.		
7	4	420	White	Lancets.
7½	4	430	Yellowish white	Surgical instruments.
8	4	442	Very pale yellow	Best razors.
8½	4	450	Pale straw	Razors.
10	4	470	Full yellow	Common razors and large pen-knives.
14	4	490	Brown	Shears, scissors, cold chisels.
19	4	510	Brown, dappled with purple	Hatchets, plane irons, pocket-knives.
20	4	530	Purple	Table-knives, large shears.
48	4	550	Bright blue	Swords, watch and bell springs.
50	2	558	Full blue	Fine saws, augers.
Boiling linseed oil		600	Dark blue	Pit and hand saws.

Those colours ranging from *straw*, for very hard ground, to *bright blue*, for mild ground, are commonly selected for tempering rock-borers, picks, &c., according as the ground may require them to possess greater or less hardness. When hard ground is also very cellular and much fissured, so as to cause unequal strains on the cutting edges of the tools, then it is necessary to lessen their liability to break through brittleness, by adopting a somewhat lower temper than would be adapted for use in ground uniformly solid.

By far the best temper for boring and other tools is that obtained by heating them only so much as shall, upon quenching, give the proper

hardness at once. To perform this it is, of course, not necessary to heat the steel as much as for full hardening, and therefore such considerable and irregular strains are not produced within the steel as are often evinced by water cracks and the breaking away of pieces under slight strain. Tempering, without first hardening, as just mentioned, requires much judgment regarding the proper heat, which is dependent upon the nature of the steel, whether mild or otherwise. The system is always attended with some failures, often to such an extent as to preclude a pursuance of it.

Passing to another subject—that of *fuel*—which is of some importance in the preparation of miners' picks, boring tools, &c., a few observations will suffice.

Coal that is slightly caking or binding in its nature is most useful for a smith's fire when an intense heat is required, seeing that the heat is reflected and concentrated within the vault formed before the blast; and such coal yields plenty of flame when required for any purpose. The most important points relating to any forging coal are the quantity and nature of the ash and clinker or cinder which result from burning it. A coal may yield a large quantity of ash, yet be useful for pretty high heats, providing the

ash is white, and does not form any sticky cinder upon the "heats." Many caking coals contain a considerable amount of iron pyrites, which is occasionally invisible, but more generally can be seen in the form either of yellowish spots, crystals, or thin plates. Iron pyrites consists solely of 8 parts of sulphur, by weight, to 7 parts of iron. Cold sulphur brought into contact with red-hot iron readily combines with it, and forms a sulphide of iron, of which there are several kinds, having different proportions of sulphur. On the other hand, when sulphide of iron—especially the one known as iron pyrites—is made red hot with free access of air or blast, some solid sulphur separates by sublimation, and most of the remainder flies off in gases of various compositions, while the place of the sulphur, in connection with the iron of the pyrites, becomes occupied by oxygen with which the iron forms the well-known red or sesquioxide, and this red oxide of iron so formed it is which gives the reddish-brown colour to the ashes of "red-ash" coal. During the burning of such coal the solid sulphur liberated by sublimation acts very injuriously upon highly-heated iron, or "scarfs" heated for welding, by becoming incorporated with the welding cinder, and communicating red-shortness to the iron. Some coals have clay shale mixed

with them, and occasionally silica and a little lime. The shale often forms a sticky paste upon the heats. In other coals, shale, silica, and any red oxide of iron from pyrites, form a fusible cinder which goes to the bottom of the hearth. When shale sticks to the heat, it is a source of danger to the welding, and of great irritation to the workmen. When an abundance of clinker is formed, the fire has too often to be raked out to keep the twyere clean, that good heats may be obtained. Many coals, unsuited for smiths' forges, can be made useful for the purpose by thoroughly washing them by one of the several methods in existence.

TABLE OF HEATS, MELTING POINTS, &c.

		Fah. Dg.		Fah. Dg.
Water freezes	at	32		
Olive oil freezes	„	36		
Summer heat in England	„	75	to	80
Blood heat	„	98		
Water boils	„	212		
Sulphur melts	„	218		
Tin melts	„	426	to	442
Bismuth melts	„	476	to	507
Lead melts	„	594	to	630
Mercury boils	„	661		
Zinc melts	„	680	to	700
Iron: red heat hardly visible in dark	„	700		
red heat visible in dark	„	810		
dark red heat just visible in daylight	„	980		
dark red heat	„	1,200		

	Fah. Dg.	Fah. Dg.
Iron: commencing cherry red	at 1,470	
strong cherry red	„ 1,650	
full cherry red	„ 1,800	
Silver fuses	„ 1,870	
Iron, dark yellow heat	„ 2,000	
Copper melts	„ 1,990	to 2,140
Iron: light glowing heat	„ 2,200	
white heat	„ 2,370	
strong white heat	„ 2,530	
bright white heat	„ 2,700	to 2,900
Cast-iron melts	„ 2,740	to 3,090
Steel fuses	„ 3,090	to 3,450
Wrought-iron fuses	„ 3,450	to 3,800

BORERS.

Tools for penetrating rocks by bore-holes are every day contributory to the accomplishment of the miner's ultimate purpose. The rock-borers, we have to notice, work either by *percussion*, or by *revolving* under weight or pressure. They are sometimes termed "drills" or "augers."*

The cutting or operating part—termed the "bit"—of a borer is nearly always formed of steel.

Percussion borers are by far the more extensively used. It is difficult to get a steel bit to stand well for a revolving borer, except in rocks which are not very hard, such as coal, salt, &c.†

* Nitric or hydrochloric acid, passed down a small funnelled glass tube drop by drop, is capable of making vertical holes in some rocks. Limestone, magnetic ore, and native copper have been acted upon in this way. Iron pyrites also, which is somewhat impregnable to a steel bit, will yield to this treatment. The process is slow. Acids are also used for enlarging the bottoms of holes to receive the charges.

† Very hard minerals—black diamonds—mounted on the end of a revolving borer, have been found to answer very well, excepting their expensiveness.

In percussion borers the *blow* is frequently produced by the force of gravity acting upon the tool itself. The common "jumper" represented by Fig. 1 is an example. It consists of a bar of iron with a steel bit formed on each extremity, and having a swell or "bead" formed between, to give it greater weight. The bead divides the jumper into two "stocks" of unequal lengths. The shorter one is used for commencing a bore-hole, and the longer one for finishing it, and often the bit on the long stock is made a trifle smaller than the other, to remove any chance of its not *following* into the hole which has been commenced.

To properly use the jumper, it must be held by both hands in the direction of the required hole, and a series of sharp blows must be produced, by lifting it up about a foot high and letting it drop, assisted by a little force, so that by the concussion of the bit against the rock, the latter gets gradually pounded or nibbled away, and by slightly turning the jumper between each blow, a round hole can be bored very truly with a little expertness.

The jumper is well adapted for boring ordinary holes which are intended to be *vertical*, or nearly so; but it is not suitable in other cases. Although very serviceable tools in quarries and open cut-

tings, jumpers are not often used underground; but it is found more convenient to use instead borers having bits at one end only, so that the comminuting effect may be produced by *striking* on the other end with a hammer or sledge—the borer being turned slightly between each blow, to secure a round hole in the rock. These are sometimes called "striking borers" for distinctness, and they are most extensively used.

The jumper is considered to have what is termed a *liveliness* in its fall—due to *direct* impact —which gives it greater effectiveness in cutting vertical holes than accompanies the use of the striking borer under similar conditions.*

Frequently the steel bits of borers get broken or blunted in use, and the re-sharpening of them is the work of a smith—sometimes requiring the employment of considerable skill. A smith who can sharpen well is always held in esteem by miners having to work in hard ground, and, to say the least, he is a valuable miner's coadjutant.

If a borer is to stand well, five things must be

* Whenever it is possible, it is usual to keep water in a bore-hole, to facilitate the work and to assist in preserving the sharpness of the bit. This converts the boring dust into a wet sludge, and to keep it from splashing out and over the person boring, a piece of leather, having a hole in the middle, is placed over the stock of the borer, thus forming a collar above the mouth of the hole. Sometimes a small hay-band is wrapped around the stock instead.

secured, viz.: 1st, good steel; 2nd, good smith's coal; 3rd, a well-shaped bit; 4th, good tempering; and 5th, fair jumping or striking, and good turning when the borer is in use. There are also two things to be avoided, viz.: 1st, overheating in the smith's shop; and, 2nd, very heavy blows in forging.

Before steel was as plentiful and cheap as at present, all borers were usually made of bars of iron, with a tongue of shear or blister steel welded in a "split weld" at the extremity, intended to form the bit. At many places these borers are still used.

Shear-steel is most suitable for forming the bit, and, to preserve its good qualities, a careful smith will sometimes draw out the iron to overlap the steel like two ears—sprinkling over plenty of sand or borax to form a flux, in order to keep the steel from losing its nature in the fire. Sometimes the steel and iron will be heated separately—the steel tongue, heated to bright redness, being put between the split of the iron bar upon drawing the latter out of the fire with a welding heat.

Striking borers of this class are now being superseded by borers made entirely of *cast-steel*, which is generally drawn under the tilt-hammer into octagonal bars called "borer-steel."

A bar of *steel* being stiffer and stronger than *iron*, admits of using steel borers with stocks of a smaller diameter—*i.e.* lighter—than if made of iron. Consequently a hammer-blow of given intensity will be transmitted with greater effectiveness through a *steel* borer than an *iron* one, because—independently of its superior firmness or solidity of texture—to satisfy the *inertia* of a borer, the lesser quantity of matter in a steel one will not require to appropriate as much of the effect of the blow as in the case of a heavier iron one. This is also one reason why a *short* borer is more effective than a *long* one. We have in some cases realised like advantage by using very small steel stocks, *upset* at the bit end to the usual size; but these borers require more than ordinary care. The use of steel borers is, moreover, favoured by their comparative lightness for transport through the mine; but they are more easily broken than iron by careless conveyance.

Some sorts of borer-steel are greatly superior to others. Actual use is the only reliable test. We have referred to this subject in our Introduction. Many different qualities are in the market at from £28 to £60 per ton. The price is a very poor criterion to quality. Good shear-steel for iron-stock borers costs from 45*s.* to 55*s.* per cwt.; blister-steel about 35*s.* per cwt.; and suitable iron

from £8 to £10 per ton. Common iron bars, hard and crystalline, answer well.

Experience has always shown that *good coal* is of great importance in forging and tempering steel. The impurities of dirty coal affect the composition of steel, and probably its molecular arrangement, so as to impair its most valuable properties. This subject has also been before alluded to.

The bit of a borer is generally formed by flattening and spreading out the end of the bar until about a quarter of an inch thick, and a little wider than the diameter of the hole intended to be bored. A sharp edge is then hammered or filed up, and the corners hammered in at intervals, until the width of the bit corresponds with the diameter of the intended hole. Sometimes the edge is filed up with a rasp; but when it has to be used in boring hard ground, it is better formed by tapping with the face of a light hammer, and afterwards touching it up with a file.

The edge is sometimes made "straight," as in Fig. 2, or "bowed" (curved), as in Fig. 3. In a set of borers intended to work in succession, if any difference is made in the widths of the bit, the long borers should be slightly narrower than the short ones, to allow them to follow easily in deep holes.

The shaft of a borer is generally from a quarter to three-quarters of an inch, and for the larger sizes an inch, smaller in diameter than the width of the bit when finished. In very hard ground the corners of the bit break off if it is much wider than the diameter of the bar.

The following are about the average proportions of the diameter of the *stock* to that of the *hole*, employed with borer-steel :—

Diameter of hole or width of bit.	Diameter of stock.
1 inch	$\frac{5}{8}$
$1\frac{1}{8}$ "	$\frac{3}{4}$
$1\frac{1}{4}$ "	$\frac{7}{8}$
$1\frac{1}{2}$ "	1
$1\frac{3}{4}$ "	$1\frac{1}{8}$
2 "	$1\frac{1}{4}$
$2\frac{1}{4}$ "	$1\frac{3}{8}$
$2\frac{1}{2}$ "	$1\frac{1}{2}$

The contained angle between the two sides of the cutting edge, as seen in section across the edge itself, and represented by Fig 4, is commonly about 80° or 90°, but varies from 60° to 100°.

In free-boring ground, or ground which is *tough*, but not *hard*, the edge may be rather acute ; but in hard ground the edge should have greater obtuseness.

A curved or bow bit is stronger in the corners than a straight one, consequently in hard ground

the bow bit is the better one for standing; still, in softer ground the straight bit answers well, and is considered to cut its way more freely, but it is not so readily forged.

By hammering in the corners of a bit, care should be taken to preserve the splay throughout to the extremity, by properly inclining the face of the hammer. When this is neglected, the corners get "nipped," as in Fig. 5, and the bit will not free itself in cutting.

When one part of the edge of a bit is "backward," as shown by Fig. 6, or when a bit is "odd-cornered," as in Fig. 7, the onward parts have to bear too much from the blows; for, by turning the borers in the holes, these parts have constantly to cut away the rock, while the other parts do not encounter any work. In this way the edge soon gets damaged, and frequently the overstrained part flies off, and causes much trouble by remaining in the hole. We have examined blunted and broken bits having such defects, and found that some parts of the edge had not even touched the face of the hole while in use. If a smith has a good eye, he can largely obviate the defect here mentioned; but the best sometimes fail. Somewhat recently the writer's father contrived a tool for sharpening borers, which gives satisfactory results. It is represented

in two side views by Figs. 8 and 9, and is simply a kind of *swage* made of steel, and having, in the bottom part, a groove of the same form as the edge of the bit is required to assume. The swage is placed upon the heated and flattened bit end of the borer—which is represented by dotted lines—and a few blows struck on the top of the swage mould the bit, and form an even and uniform edge. After the corners are hammered in, the swage is again applied, and another blow or two struck upon it.

When curved edges are required, the swages can be made three or four at a time, all centred on a lathe face-plate, as shown in Fig. 10, and the sharp V groove can be turned out of the lot with a bent V point tool. They can be used also as *bottom* swages, and the borer-bits hammered down *on* them; but there is some difficulty in keeping the scale out of the groove.

The greater durability of borer-bits sharpened by the tool described is referable to the regular evenness of the edge, and the effect of the swage in compacting the steel without straining its particles, as in the ordinary case of hammering the edge, first on one side and then on the other, in succession.

The tempering of bits exercises an almost paramount influence upon their durability and service.

When the rock to be bored is very hard, or when traversed by hard veins or interspersed with nodules of closely-compacted siliceous and other obdurate minerals, then very careful tempering is required.

Some elvan courses and tinny capel are almost impenetrable; so that a hundred borers are known to have been blunted in them by two men in a single core, and all the work done for it would be about three inches of boring, costing over 2*s.* 6*d.* per inch. Compact iron pyrites also defies penetration in a very similar way.

But when the rock is of a more yielding nature and of equable texture, then great nicety of tempering is not so indispensable.

The usual method of tempering borers is as follows:—About four inches of the bit end—previously sharpened—is heated to cherry redness in the fire.* It is then immersed in cold water to a depth of about three-quarters of an inch, and thoroughly chilled or "hardened."† The remaining

* If it is so arranged that sufficient heat remains in the bit end, after sharpening, to avoid again exposing it to the fire, and to proceed to temper direct from the anvil, it is better than reheating for tempering, and thereby further submitting the steel to the effect of the blast and heat.

† At this stage of the process the bit should not be steadily held in one place, but it should be slightly moved up and down in the water, else the hardness will terminate abruptly in a line corresponding with the surface of the water, and the different conditions of the molecules of steel above and below

hot portion is next plunged in altogether for a short time, still leaving sufficient heat in it for tempering, and then the borer is entirely withdrawn. The heat still remaining in the body of the borer and adjoining the bit will be conveyed through the particles of steel towards the hardened edge, and the hardness will be thereby reduced, while the increasing temperature of the bit will be marked by first a *yellow* and then the succeeding hues, creeping on towards the edge. If the scale be rubbed off with, say, a little grit-stone, the colours are very plainly visible, and when the proper tint appears, the borer is plunged into water, and the tempering finished.

After first observing the proper tint, instead of plunging the bit finally into water in the usual manner, if the edge is simply dipped in—say half an inch deep—it will be chilled sufficiently to let the colour creep on again, so that the same colour can be produced in this way three or four times before final cooling, and when the trouble is taken an improved tempering is believed by many to result; but it is not often practised.

With bits having much convexity or bow, the colour creeps on to the corners before it reaches

that line will there render the borer weak, and almost certainly cause it to break off at that point during work. Numerous persons are perplexed through not recognising this cause of fracture.

the middle, so that it has to be checked by dipping the corners in the water, otherwise the middle would be too hard or the corners too soft to stand well.

Almost every different sort of steel requires its own peculiar tempering, and thus sometimes an excellent steel, through not being properly manipulated in this respect, has been condemned by smiths and miners. Afterwards, when the smiths get into the way of tempering it, the same steel might give great satisfaction to all parties.

The colours for tempering bits mostly vary from *straw* to *purple*. The shades of brown give excellent tempering for many kinds of rock.

The best degree of tempering depends as much upon the condition and nature of the rock to be bored as it does upon the character of the steel; and smiths can secure considerable advantage by observing the results of different temperings, as indicated by the blunted bits from various sorts of ground. If the edges *blunt* very much by wearing off round and smooth, they may be tempered a little harder; but if they *break* and crack off very much—unless due to burning the steel, or the fault of holding the bit *still* in hardening—they may be tempered a little softer to advantage.

Oil-tempering is not often used for borers,

but it is advantageous when having to deal with some extremely hard and brittle rocks. The bit is first *hardened* by sudden cooling in water. The hardness thus produced is next tempered by slow re-heating while smeared with oil, until it *flames*, whereupon it is finally cooled by immersion. When moistened over with oil, and cooled in the same fluid, the bits are believed to acquire greater elasticity and toughness.

As steel is known to suffer injury by heating for frequent hardening and tempering, it is sometimes beneficial to avoid high hardening and subsequent tempering, by giving the steel its *final* degree of hardness direct by the first cooling. To do this, instead of heating the steel red hot at random, as in the case of high hardening, it must be heated to a *particular degree* for each stage of hardness required, and cooled at that temperature, by which means all tempering by *drawing down* is avoided, and the required amount of hardness is obtained by the first cooling.

Heating the steel to the exact temperature is the main point to be secured. This has been referred to in the Introduction. A cheap and enduring alloy, melting at the proper temperature for this purpose, would be extremely useful for heating for the operation.

Unfair blows, and bad turning when a borer is in use, will spoil bits almost as quickly as anything. The force of the blows for boring to the best advantage depends chiefly on the nature of the ground and the size of the bit. As a rule, in having to encounter very dense, sharp rock, the borer will not bear beating as heavily as in more impressible yet tougher rock, such as some sorts of killas and hornblende. Generally speaking, heavy blows are not desirable, "smart blows and plenty of 'em" being preferable, and intelligent miners always notice what strength of blow answers best.

Nearly as much depends on the *turning* of borers; and if this is not done well, so as to keep the hole round and true, the bit suffers undue strains, and soon gets impaired.

Under these circumstances, it is a matter of no surprise that the same bit will go through much more ground with some men than with others.

Cast-steel should never be heated above bright cherry red. In all particular cases it should be worked at a *dull* red if possible. In fact, the *lowest* heat at which all kinds of steel can possibly be worked is always the *best* heat.

Overheated steel is apt to *fly* or *crack* in hardening. Its fineness of structure, elasticity, and cohesiveness are also greatly injured, and this

injury increases with the intensity and frequency of overheating.

Although overheated or burnt borers do get sent underground, they are of poor use there, and are very soon sent back again. Further, they never can be of any good until the burnt part is broken or cut off. Good steel is often blamed from neglect in this direction; and when mine managers and agents give a little attention to the smith's shop, now and then taking a borer out of the fire, and properly reprehending any cases of having in the fire too many tools to attend to, or of some being overheated, the results are surprisingly modified for the better.

In forging steel, very heavy striking should be avoided, because it is known to impair the texture of the steel; and hence, in drawing out borer bits on the anvil, this should be borne in mind.

Ordinary bore-holes for blasting range mostly from $\frac{7}{8}$ to $1\frac{1}{8}$ inch diameter for single-hand boring, and from $1\frac{1}{8}$ to about $2\frac{1}{4}$ inches diameter for double-hand boring.

A smith and striker will usually sharpen and temper from thirty to forty-five medium size single-hand borers per hour, according to how much they are blunted or broken, or from twenty to forty medium size double-hand borers in the

same time. These will be hardened in water, and the colour brought up once in tempering.

By use in hard ground, borers shorten rapidly. In striking borers this shortening goes on at both the *bit* and *striking* ends. The wear at the bit end is governed by the quality of the steel, sharpening and tempering, and the nature of the rock to be bored, as well as the character of the striking. The wear of the striking end also depends upon the quality and condition of the metal of which it is formed, and the character of the striking and the rock.

Wrought-iron borers, when not steeled on the striking end, wear away very fast—especially so with poor and badly-welded or "hollow" iron.

Good cast-steel borers stand decidedly better; but they should always be well annealed on the striking end. Should the steel, however, be *rash*, it will wear down quickly, even with the best annealing, and pieces four or five inches long will often spall off the side of the borer at the striking end.*

In very hard ground some steel will do good service at the bit end, but stand very indifferently at the striking end, and this is a consideration

* Borers which have been some time in use are considered to transmit the blow better than new ones. This applies mainly to borers with iron stocks, the structure of which becomes conspicuously changed by repeated concussion.

which should be attended to in selecting borer-steel. If new borers be marked in the middle with a centre-punch, and their lengths measured, the rate of wear and tear of both ends can be ascertained at intervals, under different conditions.

The writer found, from carefully-noted results, that some sorts of steel wasted away from two to three times faster on the striking end than on the bit end; and that in the same kind of ground one sort of steel stood three times the work of another, and, notwithstanding the extra striking to which it was thus submitted, the striking ends did not wear down any faster, although both sorts were sharpened, tempered, and annealed to the best advantage.* The great quantity of steel used in British mines is ample reason for noticing this subject, and mine agents would often derive useful information by recording such results for themselves. It would invariably inculcate the principle that *the use of inferior steel is attended with loss and disadvantage,* and that *careful sharpening and tempering pays best in the long-run.*

It is almost a cruelty to provide bad steel for miners, or to make them receive their tools from the hands of an incompetent smith; and when they have to pay for the steel wasted, it is proper

* Steel thimbles, with thick tops for striking on, are sometimes driven on the borers to keep them from wearing on the striking end.

for masters to see that their earnings are not epitomized by the expense and waste of time consequent upon carelessness on these points.

The bits we have noticed are the commonest forms in use, and for most cases of ordinary hand-boring they are unexcelled. Other forms are in use, particularly in some foreign mining districts.

Fig. 11 represents the "swallow-tail" bit. It is rather weak, and requires to be used with care in very compact rock. In some sorts of ground it cuts rather *dead*, but it makes a good hole, as the width of the corners contributes to removing any ruggedness from the sides. The "club" bit, Fig. 12, has two cutting edges crossing each other at right angles, so that the impact of the blow is divided over more cutting edge. This is an advantage in some mild and some hard rocks, which would require light striking on a single edge. Fig. 13 represents the "nicker" bit, having a cross edge at one corner for cutting the circumference of the hole, and keeping it round.

All of these bits are troublesome to sharpen when they break, and it is difficult to temper them equally.

Some bits, instead of being curved *outwards* or bowed, as in Fig. 3, are curved inwards—

crescent-like—but the corners are necessarily very weak.

Revolving borers are generally turned direct, either by a lever, crank, wheel, gearing, or some such contrivance.

Fig. 14 represents a revolving bit, sometimes used for hand-boring in coal for "benching-down," either by explosives or by hydraulic benching-down machines, instead of wedging. The bit fits into the end of a mandrel, sometimes made hollow, and out of a piece of wrought-iron gas-pipe.

When used for making holes to receive benching-down machines, a fine thread is in some instances cut around the outside of the mandrel, which passes through a nut fixed in an upright prop, and the prop is secured firmly between the floor and roof by end screws or wedges. Upon turning the handle, the nut forces the mandrel and bit to advance, and thus the borer is self-feeding. A worm is sometimes coiled around the mandrel to clear out the boring dust.

We shall conclude this chapter by noticing some boring bits used for sinking artesian wells, or deep exploratory bore-holes. The bits are usually fastened by a key, or screw joint, to the tail of the rope or rods which descend into the hole.

Fig. 15 shows a "bow" bit, which is exten-

sively used. Sometimes the edge is formed as at *a*, and then it is called a "V" bit.

Fig. 16 is a double nicker bit, with a straight edge, and is a very serviceable tool. In some instances only *one* corner has a nicker, and its width is equal to about half the width of the bit. It is bent, to fit the circular form of the hole. This is called a "T" bit.

Figs. 17 and 18 represent bits which present a good deal of cutting edge, but are difficult to resharpen when broken. They both answer very well for fair ground. The "S" bit cuts a very true hole. For boring holes of large diameter, instead of using *one large* bit, it is better to use *separate* bits of a convenient size for sharpening, and all made to screw firmly into one iron block.

In some instances the bits are arranged around a cylinder for the purpose of cutting "cores," as shown in Fig. 19.

All these are percussion borers, and they generally act by the force of gravity.

For penetrating soft ground, such as clay, *revolving* borers are preferred. One of these is represented by Fig. 20, which is an "auger shell" for scooping up the clay. In some cases there is a valve inside, opening upwards, for keeping the stuff from falling out when it is being drawn up.

For boring in *hard* clay, or loam, the "nose" of the bit is shaped similar to the dotted lines, and there is a narrow slit all up the side of the shell. The stiffer the clay the wider the slit may be. Sometimes a similar tool, forming half a cylinder, like a carpenter's barrel auger, is used in like manner.

Figs. 21 and 22 show other tools used for penetrating stiff clays. Fig. 21—the "worm auger"—is occasionally used for loosening the stuff in bore-holes.

The patterns of borers employed in well-sinking and trial borings are very multifarious, especially those used in soft ground.

HAMMERS, SLEDGES, &c.

THIS class of tool is of indispensable service, because it admits of *storing* up *power*, that it may be, with convenience, given out abruptly in the form of a *blow*, which is useful for the purpose of striking. The striking part of the tool (called the "head") is proportionately massive, and for most purposes made of metal. It is usually furnished with an "eye" for receiving a wooden "handle," "stick," or "helve." When such a tool is made with a metal head, and is intended to be used with *one* hand, it is called a "hammer." When intended to be used by both hands, it is called a "sledge."* Miners' hammers and sledges are of various forms and dimensions. A variety of patterns (as used in various mining districts) are illustrated. Fig. 23, called the "bully" pattern, is a very frequent form. Fig. 24 is the "block," Fig. 25 is the "pointing," Fig. 26 is the "bloat," and Fig. 27 the "plug" pattern. The striking face is called

* Hammers and sledges are sometimes called "mallets," but the name properly refers to *wooden*-headed tools.

the "pane," and it has generally a little convexity when new to allow for its wearing.

The shape of the "head" is sometimes modified by varying its width, as in Fig. 28, which is termed a "broad bully," and Fig. 29, which is termed a "narrow bully." Besides this, the "head" is sometimes curved, as in Fig. 24, in which case it is said to "sweep."

Occasionally the "head" is formed with the side of the "eye," extended to form "cheeks," as at *a*, Fig. 30, which represents a "bloat" head *cheeked*.

The "eye" is commonly *oval*, as in Fig. 23, but sometimes *round*, as in Fig. 26, and occasionally it is *square*, or *rectangular*, as in Fig. 24; but it is varied often in the same pattern. The patterns described are drawn to represent *sledges*, but the same shapes are used for *hammers*, and the proportionate length of the head is often varied from that shown in both hammers and sledges. These patterns are used for boring, and for driving wedges and other tools to be again noticed. Fig. 33 shows the "dally" hammer, sometimes made with a circular or cheese-shaped head, and sometimes with four faces, or six (as shown), or more. This hammer is used for single-hand boring, and so is the cube hammer, shown by Fig. 34. The St. Just miners are, perhaps, unexcelled

for expert single-hand boring, and they use a hammer shown by Fig. 35, which is a long bloat-head with a little sweep. There is not usually any steel in the panes. In some other parts of Cornwall, very short, broad bully-heads are used, with the panes sharply chamfered down to about the size of a halfpenny, so that with a false blow the sledge glances sideways instead of striking the individual who turns the borer. These are called "cat's-head" hammers or sledges, and Fig. 31 represents a sledge of the kind. A miner's boring mallet is illustrated by Fig. 32. The head is usually made of a block of elm.

Hammers for single-hand boring range from 2¼lbs. to 4lbs. weight. Some miners like them lighter than others, and much, in this respect, depends on the nature of the work. For boring *downwards*, as in under-hand "stoping," heavier hammers can be used than for *horizontal* or *upward* boring.

Sledges used for double-hand boring (*i.e.* in the case of one person striking the borer while another turns it) vary in weight in the "head" from 4lbs. to 10lbs. for the same reasons as do hammers. A very convenient weight for a boring sledge-head is 7lbs. or 8lbs.

The handles of boring hammers are from 6 to 18 inches long; but in boring sledges the handles

range from 18 to 30 inches long, common lengths being 24, 26, and 28 inches.

Sledges used for driving wedges are almost identical with boring sledges, and very often the same one is used for both purposes. Wedge or gad driving often injures sledges more than boring, so that some miners like to use a particular sledge for each purpose. In some collieries a special kind of sledge is used for wedging down coal after holing. It is commonly a pointing sledge, with a head 10 to 15 inches long, by from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches square in the thickest part, tapered to about $1\frac{1}{8}$ or $1\frac{1}{4}$ inch at the panes, with the angles taken off by a chamfer gradually increasing from the eye to form an octagon shape at the panes. The weight of the head varies from 4lbs. to 10lbs.; a very serviceable weight being 8lbs., with a head 12 inches long by $2\frac{1}{4}$ inches square over the eye, tapering to $1\frac{1}{4}$-inch octagon panes.

It will be noticed that most of the hammers illustrated have two striking "stumps," with panes like each other. Miners are partial to this form, because it balances well in the hand.

Sledges are frequently required for breaking up lumps, and as this work is very rough usage for a sledge, there is often one of a particular form used for the purpose, and called a "lump

sledge." The weight of the head is from 10lbs. to 20lbs. It has usually egg-ended panes, but varies in shape. Fig. 36 shows a lump sledge used in some metalliferous mines.

Fig. 37 shows a "cobbing hammer" used for dressing ores by hand. The head varies from 14 to 18 inches long, and from 2lbs. to 4½lbs. weight. Fig. 38 represents a "bucking iron" with the stirrup (to receive the handle) welded on the back of the striking-plate. This is used for hand-crushing in dressing ores. Fig. 39 represents another bucking iron, in which the handle is secured in the stirrup by a wooden wedge driven on the back of the striking-plate. The adoption of rollers and other crushing machinery is gradually dispensing with the use of these tools.

The "spalling hammer" is used for breaking up lumps of orey mineral for sorting before crushing and stamping. The head weighs generally about 2lbs. or 3lbs., according to the class of work to be done. It is shaped similarly to the pointing pattern, Fig. 25, but with spherical ends—almost identical with the common road-metalling hammer—and furnished with a handle about 26 to 30 inches long. Spalling hammers are not intended for cleaning ore fit for market, as are cobbing hammers.

Sledges are often made at the mines where they are used. The head then consists of wrought-iron with steel panes. The *eye* is generally punched hot, out of a short square bar of iron of suitable size, and a drift is worked in to keep the eye in shape while the sledge is being forged.

Bar-iron being generally manufactured by rolling, at a welding heat, a pile of separate pieces of iron, has often a *laminated* or *leafy* structure, due to imperfect welding in its manufacture, which can be detected on inspection. Fig. 40 shows this laminated feature as it would appear in the section of a bar.

When sledges have to be made out of such a bar, the eye is not as strong if punched *with* the laminæ, according to Fig. 41, as if punched *across*, as in Fig. 42. If sledges are to stand well, it is important to punch the eye *across* the laminæ; but many smiths overlook this point, and sledges punched the other way are constantly splitting in use. Bully-heads are often forged as follows:—

A bar of iron, say 2 inches square and 13 inches long, is cut off. This will make two 8lb. sledges. One set of corners is chamfered down in the cutting-off heat, as shown by Fig. 43. The eye, *a*, is next punched, and then *b*, and the sledges

are divided by a clift, one set of corners being chamfered down, as shown by dotted lines, all in the same heat which was drawn for punching *b*. Afterwards the other sets of corners are similarly chamfered down by new heats, and both sledges are ready for "steeling." For this purpose is used a flat bar of good *blister* or *shear* steel of about 2 inches wide by $\frac{5}{8}$ inch thick. One end is heated to redness, and after about 2 inches have been nearly severed with a clift, as in Fig. 44, it is bent, and two corners hammered down on the anvil, as in Fig. 45. Then, by bending it the opposite way, the two other corners are hammered down similarly, as in Fig. 46, where it assumes an eight-square outline, and forms a pane for the sledge, attached to the bar by only a slender neck. The steel pane is next welded on. This is done by heating the steel and one end of the sledge separately. When a welding heat is drawn—sand having been used to form a glaze—the sledge is rapidly placed on the anvil, with the heated end uppermost, and the hot steel pane being quickly laid on, with the sides corresponding with the iron part, as in Fig. 47, a few light hammer blows on the surface of the steel pane weld it firmly to the iron, and by twisting the steel bar it breaks off at the narrow neck, leaving the pane properly attached.

The chamfers are then dressed with a hammer, and after the opposite face has been treated similarly, the sledge is hardened by heating both faces to redness, and plunging it into cold water until quite chilled, upon which it is finished. Although the faces are not *tempered* at all, they are often found to be too soft, and this arises from the violent ebullition which the hot sledge produces when immersed, and which prevents the water from coming into close contact with the steel, so that it is cooled too slowly to be sufficiently hard. If streams of cold water are made to play with some force against the hot panes, they are always found to be well hardened.

When these sledges are made well, out of good iron, they stand a great deal of wear, and possess the advantage of being easily re-steeled when the panes are worn out. If, however, they are defective in quality, or workmanship, they are very liable to break by splitting, or giving way across the eye. A smith and two strikers will commonly forge *eight* 7lb. bully sledges per day, and turn them out of hand in a workmanlike manner. This is a fair day's work, although some smiths, after getting well used to the work, can do ten. The cost may be arrived at as follows:—

1 Smith at 5s.	= 60 pence.		
2 Strikers at 2s. 6d. (5s.)	= 60 ,,		
Labour		120 pence.	
50lbs. iron, say	50 pence.		
8lbs. steel, say	32 ,,		
		82 ,,	
Total		202 pence.	

Weight of sledges $8 \times 7 = 56$ lbs.

Then $\frac{202}{56} = 3{\cdot}60$ pence per lb., or nearly $3\frac{3}{4}d.$

The cost of coal, wear and tear of tools, &c., would amount to a trifle, say $\frac{1}{2}d.$ to 1*d.* per lb., extra.

Similar sledges can be bought ready-made by the cwt. at about the same rate; but they do not, as a rule, stand as much work as home-made sledges, and it is sometimes necessary to make sledges at the mine in order to fill up the smith's time. A smith and striker can re-steel about twelve of these sledges (twenty-four panes) per day. Excellent solid cast-steel sledges are now procurable from steel manufacturers at 9*d.* per lb. for sizes above 6lbs. weight, and increasing to 1*s.* per lb. for smaller sizes. Occasionally these sledges break by cracking, after which they cannot be repaired; but if they are well made, and used carefully, they are remarkably durable, and are becoming very favourite amongst some miners, many of whom claim that they give a "smarter" and more effective blow than steeled iron sledges.

PICKS.

THE pick is notably a miner's implement. In different districts it is called either a "mandrel," "pike," "slitter," "mattock," or "hack."*

Fig. 48 shows the common pick. The head is usually made of wrought-iron with steel at the "tips," *a*, *a*, *b*, *b*, which form the wearing parts. An eye is formed at *e*, to receive the handle or "helve," which is secured by a wedge (shaded dark), and the sides of the eye are spread out to form "cheeks," as at *f*. About half of the head, viz., *f*, *a*, or *f*, *b*, is occasionally termed a "shank," or "stem." The "helve" is ordinarily made of ash; and the part *g*, formed to suit the eye, is called the "feather," while *h* is called the "haft," which is made of a suitable size for holding in the hands, and is usually oval in shape. There are many other patterns of picks to be noticed presently.

The action of a pick is very similar to that of a sledge, but the tools are of different utility. While

* This tool is said to be represented on Egyptian monuments of great antiquity.

The last use to which a pick is applied, which we shall notice, is that of a *scraper*, which is occasionally required in narrow cuts for dragging out the stuff loosened by working.

In Fig. 48 the head of the pick is *curved* slightly. When this is the case, it is said to "sweep." Picks, as Fig. 60, having straight tips converging to the eye, instead of being curved, are said to be "elbowed" or "anchored."

In some picks there is no curvature, and then the head is said to be "straight," as in Fig. 50.

For *under-hand* work, a pick having a little sweep is preferred, because, as miners say, it "falls" into its work better than a *straight* head; but for *over-hand* or *long-reaching* work a straight-headed pick is generally chosen, or one having but very slight sweep.

Straight-headed picks assist the reach, and are best for getting into *corner* work.

As in the case of sledges, the weights of pick-heads vary according to the preferences of the users, and the sort of work to be performed. From 2lbs. to 8lbs. are the common extremes. When required chiefly for *downward* cutting, heavier picks are used than for *horizontal* or *upward* work; and it is usual to employ heavier picks in hard ground than in soft.

The stems are commonly rectangular in cross

section—the angles being sometimes chamfered down—and they are from $\frac{1}{2}$ inch to $1\frac{1}{4}$ inch thick near the eye, according to the shape, strength, and weight required. Very commonly the stems are square in section, but often they are flattened sideways to make them deeper in the direction of the helve, as in Fig. 63. This gives them greater strength for prizing. Fig. 49 represents a form of pick in very common use in iron mines. It is forged out of $1\frac{1}{8}$-inch square iron, and weighs about $4\frac{1}{4}$lbs. when new. A similar pick, largely used for the same purpose, is forged out of 1-inch square iron, and weighs $3\frac{1}{2}$lbs. For working loose or soft iron ore, picks of the same shape made out of 1-inch square iron, and weighing 3lbs., are often preferred.

The helves in these picks are generally from 24 to 33 inches long. The length varies according to the nature of the work and user's taste; it being further influenced in some cases by the size of the lode or deposit to be worked.

Fig. 50 represents a coal pick in common use in the Gloucestershire and Somerset collieries for "holing" and "cutting" purposes.* The head is

* The operation of under-cutting the coal, so that it may afterwards fall, or be wedged or blasted down, is called "holing," "benching," "kirving," or "under-going." The long gash, jad, or jud, cut for this purpose parallel to the plane of the seam does not sometimes exceed 8 or 9 inches in width at the

double-cheeked, and weighs about 2¼lbs. or 2½lbs. A common length for the helve is 30 inches.

Fig. 51 shows the pick commonly used in the same districts for "dead work" or "deading." The head weighs about 4lbs. or 4½lbs. Fig. 52 represents a very similar form of pick, used for coal-cutting in the Bedminster part of the Bristol coal-field. The head weighs 2½lbs., and the helve is only 25 inches long.

Fig. 53 represents a holing pick slightly sweeped, as used in the Forest of Dean—weight about 2¼lbs.; and Fig. 54 represents a cutting or "cut-off" pick—used in the same place—the head being somewhat heavier.

Fig. 55 represents the form of holing pick in common use at the collieries of South Wales. The head weighs about 2¼lbs.; sometimes 2lb. heads are used. At other times two sizes are used,—*large*, with heads about 3lbs., and *small*, with heads about 1lb. less. When a long reach is required, the helve is 34 or 36 inches long. 28 and 30 inches are lengths frequently adopted. Fig. 56 represents the cutting pick commonly

front or "foreside," and it may penetrate to about 3 feet inwards, gradually narrowing. It is generally made near the *floor*, but its position depends mainly on the nature of the deposits—being often cut with advantage where a layer of soft coaly or other substance occurs in or adjoins the seam. See p. 85—holing and cutting picks.

used in the same collieries. It is sometimes the same weight as the holing pick, but often a little heavier—3lb. head. The stems, as a rule, taper regularly from eye to tip.* After holing and cutting, a somewhat stronger pick—about 4lb. head—called a "stripping mandrel," is employed, in some instances, for "pulling down" the coal. A form of "rock pick" for dead work, frequently used in the South Wales coal-fields, closely resembles Fig. 48, the head being about 6lbs. weight. Another form resembles Fig. 49, with a $4\frac{1}{2}$lb. head. "Bottom picks" are also used in the same locality for cutting the *floors* or *thills* of coal seams. These are often shaped like Fig. 49, and sometimes like Fig. 57, with 5lb. or 6lb. heads; but when the bottom is not very hard, lighter heads are used.

Fig. 58 represents a holing pick, with about a 2lb. head, used in Flintshire. It has a sweep head, and often chisel tips. The cutting pick is slightly heavier, and has points, but is of the same pattern with less sweep. Fig. 59 represents a "driving pick" for dead work, having about a 3lb. head, used in the same collieries. It is *top*-sweeped only.

Holing and cutting picks, extensively em-

* In this district new heads for cutting and holing picks often measure 20 inches long. The stems are very thin and slender.

ployed in the North of England collieries, are represented by Figs. 60 and 61. The heads weigh from 2½lbs. to 3lbs., and have very small cheeks. Fig. 60 is more elbow-anchored than Fig. 61. Fig. 62 represents a "driving" or "stone" pick, elbowed in character with the former ones, and used for dead work. The angles are not always chamfered, and the head weighs about 4½lbs. or 5lbs. In Northumberland lead-mines a pick represented by Fig. 63 is used. The head weighs about 3½lbs.

Were we to omit reference to the "poll-pick," we should overlook one of the most valuable of the British miner's tools.

Fig. 64 represents the poll-pick commonly used in Cornwall. It has one stem about 12 inches long, from the end of the eye, and one stump about 3 inches long to form the "poll." The eye is about 2½ inches long. When forged out of 1⅛-inch square iron—the thickest part of the stem—the head weighs about 4lbs., and is a favourite size for hard ground. The face of the poll is steeled like a sledge, to form a pane, so that it can be used for striking blows. 26 to 28 inches is a common length for the helve, which is slightly feathered on one side only, and curved in the haft.

The head is sometimes quite straight. The poll-pick has the "much-in-little" recommenda-

tion. It has the properties of the pick, and, in addition, it can be used as a sledge to drive in wedges, &c., thus avoiding the necessity of laying it aside and taking up a sledge for the purpose; but more than this, it can be used as a wedge itself, and, by striking it on the *poll* end, it performs very useful service in this respect, although the eye is liable to burst if thus tried too severely.

With these points in view, it is easy to understand why the poll-pick should be a favourite tool with many miners, and any one need only use it for a bare month or two to comprehend how greatly does a miner accustomed to its use feel the loss when deprived of it by any circumstance. Sometimes, for soft ground, the stem is 18 inches long, and only $\frac{7}{8}$ of an inch square in the stoutest place.

Poll-picks are used in several parts of Great Britain. Fig. 65 represents a rather stumpy form used in some hard ground by Derbyshire lead miners. The head is about $3\frac{1}{2}$lbs. weight.

Fig. 66 represents a poll-pick used by Flintshire lead miners.

In *prizing* or *levering* a pick, strain is thrown on the *helve* in the eye, thereby inducing a tendency to "wince," by the yielding of the feathered part, as shown in section by Fig. 67.

Now the bearing surface at each end of the "eye" is usually rather short and narrow, but it should be long and wide to best counteract wincing. The keener the edges of the helve feather are made, the more liable it is to wince, or to split the eye.

Prevention of wincing is aimed at by wedging the helve in the eye, so as to make it press very tightly against the cheeks and sides. This makes the helve tight; but it sometimes causes the eye to split, so that the proper amount of wedging to stop at is not always easily determined.

The mischief of wincing can be largely avoided by increasing the *end bearing surface* of the eye; for which purpose the eye should not feather very keenly, as in Fig. 68, but should rather have the ends rounded, as in Fig. 69, and the ends of the eye should be made as deep as possible in the direction of the helve, in order to give the feather, when prizing, fulcrum as far as possible from the neutral axis of the head. There is generally not sufficient regard given to this matter. We have found it an advantage, for picks exposed to severe wincing strain, to weld two corbel bits at the ends of the eye, as shaded dark on Fig. 70.

The Forest of Dean miners have a device to

a good purchase for levering, without prizing greatly on the helve.

In loose ground, light stems, each as much as 18 inches long, are at certain times used.

Continental miners have very diversified forms of picks. Figs. 74, 75, and 79 are single-stem picks, which belong to a very general class used in some collieries.* Figs. 76, 77, and 78 belong to the poll-pick class, which is very common in metalliferous mines.

Our continental friends give much more heed, in the construction of their picks, to the prevention of wincing than is manifested in this country.

Figs. 74, 75, 76, 78, and 79 give a large and long bearing surface for the helve in the eye. Sometimes the eye is lightened by cutting out the sides, as in dotted lines Fig. 74. Fig. 77, though not affording a long bearing for the helve while *prizing*, nevertheless offers a broad, flat surface at the ends on account of the eye forming a wide rectangle. Very slight wedging of the helve is sufficient for either of these picks.

The sizes of picks vary in foreign countries just as they do here. A fair variety was shown at the late Paris Exhibition. Some of them in

* A single-stem pick of this class—74—is used in our anthracite collieries.

in quarries for scabbing over the surface of large blocks of stone (to partly reduce irregularities) before they are sent to the stone dressers. A miner's "twibill" is a similar pick, with an eye generally rectangular. Fig. 85 is a form of pick-head sometimes used in Germany. Figs. 86 and 87 represent the forms of "Australian" or "nugget" picks, used in gold-mining districts, the weight of the heads varying from $1\frac{3}{4}$lbs. to $3\frac{1}{2}$lbs.

We understand that American mining picks are closely akin to those used in Great Britain, and some of them are similar to the single-stem and poll-picks used on the Continent. Fig. 88 shows a poll-pick used in some American iron mines, where it is called a "hammer-pick."

The tips of picks are sharpened on an anvil to the required form. Most commonly they are drawn out to a point like a four-sided pyramid, and this is the best form for hard or crisp ground. But when required for *chipping* the ground, or for working tough ground, a chisel tip is more suitable. Some kinds of holing ground are rather *binding*, so that a chisel tip clears it out better than a point, after the pick has entered. For this reason, chisel tips $\frac{1}{4}$-inch wide are used for working parts of the so-called "soap" vein in Monmouthshire. When the tips taper gradually, they are spoken of as being "slim;" but when

they taper quickly, they are said to be "bluff." The rate of taper is regulated by the following considerations, viz.: the *strength* required, the *nature of the work* to be performed, and, sometimes, the *length of the head.* The bluffer the tips, the stronger they are; but very stumpy tips will not always cut the ground well, or penetrate it sufficiently. Coal picks, used for *holing* and *cutting*, are often required to work in a narrow slit or cut, to deepen or prolong it. Reference to Fig. 89 will explain why, under such circumstances, the tips must be drawn out slim, because it is necessary for the point to "catch" in the corner of the cut, and if made bluffer, as in Fig. 90, the head cannot be turned sufficiently oblique to enable the point to touch the side at all, and so with such a pick, by losing its catch, the sides of the cut would soon close together and meet, or "cut out." It will be clearly seen that the *shorter* the pick-head the more obliquely it can be turned in a narrow cut, and the bluffer the tips may be used without losing the catch.

Cutting picks are used for cutting or shearing off the coal at the sides of the stall or face, so as to part the seam on each side, and facilitate the bringing down of the coal between the cuts. These "side cuts" are generally vertical, and are

made as narrow as possible, to avoid wasting the coal.

Some good colliers will work in cuts from 2 to 3 feet deep, and not exceeding 5 to 8 inches wide at the front, so dexterously, that the *standing side*, as the face advances, will form a large surface with evenness resembling a good brick wall, and covered with marks of the pick-point, not unlike the track marks of circular-saw teeth.

The tips are tempered in the same way as borers—generally to a straw colour, or a very light blue on the extremity—by first hardening and then reducing or tempering with the heat remaining behind the extremity.

This is the right principle of tempering, because it leaves the hardest parts nearest the extremity. When picks are not blunted very much before they are sent to be sharpened (as is usually the case with coal picks), one smith and a boy can sharpen and temper in the ordinary way about 70 to 100 tips per hour; 120 per hour is viewed as brisk work. Mr. J. T. Green, manager of the Tredegar Collieries, informs us that a smith and a boy can sharpen 150 points of their picks per hour in the usual way. Two or three points or tips are generally heated in the fire together for following in succession. Some dead-work picks, and picks used in metalliferous mining, are

commonly blunted much more than coal picks, so that they take a longer time to sharpen, and often require to be drawn out a little with the striker's sledge. In this case, 40 to 60 tips per hour are as many as one smith, assisted by a striker, can sharpen and temper.

Picks are ordinarily made at the mine. One method will be understood from the following description, which, for convenience, will refer to heads weighing about $4\frac{1}{2}$lbs., a very useful size for hard ground. A piece of $1\frac{1}{8}$-inch square bar iron, about 14 inches long, is cut off. The middle part is then heated, and "upset"—by striking the bar endwise—until it forms a swell about $1\frac{1}{4}$ inch square where the eye is to be made. A gash is next cut through the middle of the swell, with a kind of clift, after which the bar resembles Fig. 91. A "drift" of the proper shape and size is then worked in, to form the eye, as shown by Fig. 92, and the sides of the eye are stretched out, by hammering, to form cheeks of any desired shape. When this is finished, each end of the bar is split, as shown by Fig. 93, and a tongue of steel (shaded dark on the figure) is welded between, to form the wearing extremity.*

After this the stems are drawn out to the re-

* The remarks on *borers* for making "split welds" apply to picks also.

quired taper,—being curved to any sweep, if so required,—and the tips are next sharpened and tempered to finish the head.* One smith and striker will make, in the usual way, twelve of these pick-heads per day, well finished and good, the labour costing about 7*d.* per pick; making the cost of the head 1*s.* 1*d.*, or nearly 3*d.* per lb. for labour and materials. If the pick-heads are about $2\frac{1}{4}$lbs. weight, and made out of $\frac{7}{8}$-inch square iron, one smith, with a striker, will make twenty per day—the cost for each head being, for labour $4\frac{1}{2}d.$, and for materials 4*d.*; in all, $8\frac{1}{2}d.$†

Poll-picks are made by the same method, only a poll is left for welding on a steel pane, instead of drawing it out into a stem. They take about the same time to make as double-stem picks of

* The eye should be punched *across* the laminæ of the bar, as in sledges.

† At some collieries in South Wales, where hard steam coal is worked, a smith and striker are paid 4*s.* 9*d.* per set, not including wedges, for labour only for making colliers' tools. The set consists of:—

1 Bottom pick .	6 lbs	25lbs.
1 Sledge . . .	$7\frac{1}{2}$ „	
5 Coal picks . .	$11\frac{1}{2}$ „	
2 Wedges . . .	6 „	

A good smith and striker, accustomed to the work, will make two sets per day, excluding wedges; and they consider it good work to make 10 bottom picks per day, or 8 sledges, or 24 $2\frac{1}{4}$lb. coal picks. By long practice, however, some will exceed this. For some of the soft seams of North Somerset, one or two coal picks with a sledge and wedge make up a set.

the same weight, and are commonly sold in Cornwall at from 3*d.* to 4*d.* per lb.

Another method of making picks—commonly practised in Somerset and Gloucestershire—is by welding together two flat bars, having the sides of the eye flattened out in them as indicated by Fig. 94. The welding is commenced for each stem at the end of the eye,—which is formed on a dresser,—and the tongues of steel, shaded dark in the figure, are welded in before the stems are drawn and tapered.

Picks made in this way stand excellently if *well* welded, otherwise they are apt to split in use. Sometimes a tongue of iron, or a "burr" from a punching machine, is welded in each end of the eye, to make it stronger; and this also increases the end bearing surface for the helve.

To make ten 4½lb. heads in this way, or twelve 2½lb. heads, and turn them well out of hand, is a fair day's work for an ordinary smith and striker.* At some collieries they pay for labour only, for making these heads, 9*d.* each for the larger, and 7*d.* each for the smaller ones.

After much use the stems of picks wear away too short for further service, but when the eyes

* Cast-steel pick-heads are sold at from 9*d.* to 1*s.* per lb., but are not much employed, on account of their liability to break.

have stood well, they are generally considered too valuable to throw aside, and the stems are lengthened by first cutting off the old tips, and then welding on new pieces of iron, putting in tongues of steel between split welds at the extremities, after which the whole is drawn out to the required taper, and shaped as in making new picks.

This is called "lining" picks. A smith generally lines eighteen $2\frac{1}{4}$lb. pick-heads — equal to thirty-six stems—in one day, or fourteen $4\frac{1}{2}$lb. heads—equal to twenty-eight stems—in the same time. This is about as much trouble as making new picks, but the advantage connected with *lined* picks is that the eyes have been proved to stand well in work.

Figs. 95, 96, and 97, show some of the chief forms of Messrs. Dâhne and Thomas's patent picks for holing and cutting coal, the particulars of which were kindly furnished us by Mr. David Thomas, Manager of the Rhymney Iron Company's Collieries. These picks have removable tips, which can be readily changed. They are very portable, weighing only from 5 to 7 ounces each, so that a miner can conveniently carry several to work, and need never be short of a sharp tool. This is equivalent to a great saving of weight and of expense in furnishing each miner's equipment. It cannot be expected

Since the socket-piece and movable bar of this pick go together to make up the whole weight of the head, it naturally occurs that for picks of a given weight, this one would not be expected to give blows quite as effective as the ordinary pick, in which the head is made of one entire piece of metal, so disposed as to be very direct and effectual in its work; but the merits as regards facility for renewal and transport are of very material consequence in some instances, and the firmness and simplicity of this particular arrangement are highly spoken of.

In the specification diagrams, the legs or straps of the socket-piece, which embrace the helve, are seen to be so tapering as to converge towards the extremities. Fig. 98 is drawn accordingly, but it is not clear how the helve could be got into the socket under these circumstances, since the screw-boss prevents its being passed in at that part, and the feather or spreading end of the helve is too wide to pass between the straps in the reverse way. But this is merely a matter of detail, and is readily met by forming the straps so as to taper or converge the opposite way, corresponding with the dotted lines *z*, *z*, shown on one side only.

The designing of a really good pick, with movable tips or stems, is an object which has

SHOVELS, SPADES, ETC.

THE ground which is loosened and broken by blasting, and by the use of picks, and other tools to be hereafter noticed, soon requires to be collected together or shifted. The shovel is a highly serviceable tool for such work, within small limits. It consists essentially of a light "plate," furnished with a handle, or helve—the plate being suitable for scraping together a mass of loosened ground, and also for passing under a portion thereof which will afterwards rest upon it; while the handle is required for conveniently carrying the stuff thus supported, or for jerking it off to a different place, or into vehicles.

The desirability of having such a tool must have been recognised by the ancients at a very early period. An examination of the relics of some of their wooden shovels is likely to satisfy any one that they thoroughly apprehended the principles of the shape of a good shovel. To facilitate the passing of the plate *under* or *between* the stuff, they reduced it to the minimum

sides. This affords firmness, and enables the plate to sustain and keep together its load better than if quite flat. The shaded part of the plate—where it joins the straps—is buckled upward to give strength, and it is termed the "crease." The part of the plate each side of the straps is called the "shoulder." The entering part of the plate —or *mouth*—which in the gravel shovel is pointed like the bow of a ship, forms two sides, which are termed the "edges." The helve is set at an angle of about 140° to 160° with the surface of the plate, and is about 30 inches long. This is necessary in all shovels on this principle, to enable the plate to be horizontal with easy stooping by the users. The plate of this shovel is well formed to facilitate its *entering* between closely-compressed, heavy, or lumpy ground.

Fig. 100 represents a "Devon" or "long-handled" shovel, with a plate of the same class, only furnished with a "socket" for receiving a long handle, generally 4 or 5 feet long, which admits of shovelling with less stooping, and of getting a longer reach. The crease is long and pointed, to facilitate entering. These shovels are frequently used in Cornwall, Devon, and Somerset, when there is sufficient room for such "stand-off" helves. The *point* of the crease is the place at which they are most liable to break.

welded to the back. These are sold either of cast-steel or welded iron, as "graips" or "digging forks," with diamond, square, flat, or round sectioned prongs, and they are stronger than prongs riveted.

Shovels are almost invariably bought ready made. Ordinary qualities have the *plates* manufactured by rolling out, under a welding heat, two pieces of iron with a piece of steel between. The ears, having been previously drawn out, are kept from sticking together by sprinkling ashes between. Iron of inferior quality can be used by this method. Before rollers were employed, the plate was formed by spreading out iron under a weighty hammer. This is still done by some manufacturers, and as only good iron will bear spreading in such a way by "plating" under the hammer, it is considered that good quality is guaranteed in shovels made by this method.*

There are various other shapes of this class of tool. In clay ground, a "clay spade," having a

* Anvils used for "plating" are 5 to 7 inches long by 1½ to 2 inches wide. The hammer faces are somewhat smaller and oval-shaped. They are of mottled cast-iron, with chilled working surfaces ground to a slight convexity. In order that there may be a clean bright skin to the plate, it must not be heated above a dull yellow heat, else the plating tools chop in too much, and embed scale in its surface. From this limited temperature, and the action of the tools, the process is a severe test of the quality of iron.

The shovel immediately takes fulcrum at the part near the dotted lines *b*, and by the superimposed weight or resistance acting on the surface of the plate, a severe tensional strain is thrown on the crease, over the fulcrum, and on the *top* strap near where it joins the plate. Shovels often give way at this part by the breaking of the top strap, and many almost new ones are spoiled thereby. This is the weak point in most shovels, and as the prizing is, within certain limits, legitimate and necessary, shovels made with long straps extra strong at the shoulders, and strong over the crease, will always carry good recommendation.

Very good 10, 11, and 12-inch gravel shovels and round-mouth filling shovels can be bought at from 22*s*. to 28*s*. per dozen, fitted with crutch-handles complete.

Grafting tools, 12 inches by 6½ inches, with similar helves, cost about 2*s*. 6*d*. each, and 14 to 16-inch frying-pan shovels from 33*s*. to 43*s*. per dozen. Well-made iron-pronged shovels, with three to six prongs welded, and strapped helves, cost from about 3*s*. to 5*s*. each; if of cast-steel, from 6*d*. to 1*s*. each extra. The best *plated* shovels, without handles, can be bought for about 7½*d*. per lb. A 4lb. Devon shovel-plate, often used in Cornwall, is generally sold for 2*s*. 6*d*.

There is great multiformity in the shovels used

2 feet long. The trays carry about 40lbs. of mineral, and answer much the same purpose as the "billies" so commonly used in the Dean Forest iron mines by persons there employed at conveying ore upon their backs—a mode of transport which is in some measure advantageous to the working of the irregular accumulations of that district, but very prodigal when depended upon to a great extent.

HATCHETS, AXES, AND ADZES.

A MINER cannot do much in soft-ground mining without the use of timber, to cut and dress which he requires a few tools well adapted to the purpose. Those now to be considered form an important part of them.

A hatchet or axe consists essentially of a broad heavy description of chisel, called the "head," having an eye running in the direction of the cutting edge for receiving a handle, so that, like a pick in one particular, it is suitable for giving out a blow, to be expended in actuating the cutting edge, which forms part of the tool itself; the main difference being that a pick is used for cutting rock, but an axe for cutting timber.

Illustrations of several patterns of this class of tools are given. Handles shorter than those shown are often used.

Fig. 106 represents the form known as the "Irish axe," of very general use in numerous districts. The main objection to this form is that the edge gets *narrower* by wear. Fig. 107 shows

the "Yorkshire axe," not much unlike Fig. 108, which represents the "Newcastle axe." The "Scotch axe" is shown by Fig. 109, and the "Kent axe" by Fig. 110. A "claw" is often formed on the back of this axe, as shown in dotted lines, for drawing out spikes and nails. Sometimes the "claw" is put on the *under* side; and in other cases a slit, dotted on Fig. 109, is used instead of a claw. Fig. 111 is known as the "wedge axe," from its being suited for use as a wedge; and another axe, somewhat similar in that respect, is shown by Fig. 112, called the "forest axe."

The hatchet and axe are almost identical in character. Some persons consider the axe is the heavier tool, with heads weighing above 3lbs., and suited for use with *both* hands, while the hatchet is intended to be used by *one* hand only, and has a head weighing under 3lbs.

Some manufacturers consider that the difference between hatchets and axes is entirely in the grinding of the edge. When the edge is bevelled off distinctly, as at *a*, Fig. 106, it is a *hatchet;* but when the edge is rounded off gradually, as at *b*, in Fig. 107, like the bow of a ship, it is an *axe*. Axes are considered best for *splitting* and *cross* grain *hewing;* but for *chopping with* the grain, hatchets are best, because the bevel turns

off the chips, and keeps them out of the way of the head. The part *p*, *h*, Fig. 106, is the *head* in every hatchet or axe. The back, *p*, is called the "poll," and, when well made, it is strong and faced with steel, to form a surface for striking moderate blows. The "eye" lies between the cheeks *c*, *c*. The "blade" of an axe is the part between the eye and cutting edge. It is generally broad and thin, composed of a doubled piece of flattened wrought-iron welded together, with a thin piece of steel between, to form the edge. Hatchet and axe-heads used in mining may be said to range from 2lbs. to 8lbs. in weight.

In some Somerset collieries, where light timbering is practised, a 3lb. hatchet is found very handy. A 4lb. hatchet is in very general use in many districts. A 6lb. or 7lb. head is, perhaps, usually the most convenient size for a timbering axe. It is in very general use for ordinary timbering, and for rather heavy work. Axe-heads of 8lbs. weight and upwards are in common use at South Wales collieries, the pattern being like the forest axe, with the length of the head disproportionately increased so as to measure 12 inches and more when new.

Hatchet handles are generally single-feathered, and from 14 to 20 inches long. Axe handles are longer; from 16 to 26 inches, in many instances 30 inches, and occasionally as much as 36 inches.

The cutting edge of these tools is formed by grinding the front of the plate, both sides in ordinary cases, on a grindstone, so as to form two inclined planes or curved surfaces, meeting each other at an acute angle. In this manner the iron on both sides is ground away, and the steel between forms the edge.

The acuteness of the angle forming the edge should not be enough to make it very thin and liable to break, for it wastes a lot of time and material to grind out notches in order to reproduce a sharp edge. On the other hand, if the edge is *bluff* by a very obtuse angle, it will not cut well, and for chopping deep cuts it will not *catch* the sides in a narrow gash, but will require a cut to be very wide at the top to allow the head to be held sufficiently oblique.*

For chopping hard wood, the requisite strength requires a bluffer edge (a more obtuse angle) than may be used for soft wood. The angle contained between the two sloping planes to form the edge usually varies from 15° to 30° accordingly.

For chopping large flat surfaces, some hatchets or axes are always *used one way*—*i.e.*, only *one* particular side of the blade is ever used to face

* This will be clearly understood by referring to Figs. 89 and 90, relating to *picks*. The same conditions apply to the hatchet and axe.

the surface which is being chopped. This is called the *inside* of the blade, and the edge is ground very acutely on this side, while on the outside it is ground more obtusely, as shown by sections at *s*, Figs. 106, 109, and 110. Such a form of edge is very suitable for *side* chopping over large flat surfaces. The so-called "squaring axe" or "side axe," of sundry patterns, is ground in a corresponding manner.* Miners almost invariably grind both sides alike, so that the tool may be used with equal success both ways.

The "felling axe" has usually a long *narrow* blade, shaped like Fig. 113, thick and heavy at the eye, and tapering gradually towards the edge. The "mortise axe," Fig. 114, is often useful for mortising heavy timber used in large workings.

Hatchets and axes are generally bought ready made. Only the best quality can be recommended for mining. The sizes of axe-heads are sometimes classed under the following heads:—

Extra light, from 2½lbs. to 3½lbs.
Light, from 3½lbs. to 4lbs.
Medium, from 4lbs. to 5½lbs.
Heavy, from 5½lbs. to 7lbs.
Extra heavy, above 7lbs.

* Sometimes the eye of a squaring axe is altogether on the outside, as shown at *q*, Fig. 110; or like a cooper's axe.

With steel polls, good axes cost in this country: for the *light* size, about 8*d.* to 9*d.* per lb.; *medium* size, from 7*d.* to 8*d.* per lb.; and *heavy* size, from 6½*d.* to 7*d.* per lb. Solid steel axes cost about 6*d.* per lb. extra.

Best solid steel 6lb. axes, with good helves complete, are sold by some ironmongers at 8*s.* 9*d.* each.

Sham-polled iron axes can be bought for 5*d.* per lb., but they are almost worthless to miners.

Hatchets and axes are often made at the mine, and some miners think them stronger and more serviceable than those supplied by ironmongers; but they cost more than ready-made ones. Mine smiths are not, as a rule, much accustomed to making them.

Usually they form the eye by doubling over a piece of iron to make a loop for afterwards drifting to shape. The doubled part is then welded and spread to form the blade—a piece of steel having been put between to form the cutting edge. After the head is shaped as desired, and the poll faced with steel, the edge is hardened and tempered *straw* colour, and the poll about *purple*.

Axe-heads which have much "outlying," as is represented in Fig. 108, are liable to quiver in use, and to produce a tremor through the helve when the cutting comes on the outer part of the

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Fig. 169.

SAWS.

An attempt to divide thick timber with an *axe* will soon show that, in order to give the axe room to work, the cut must be a gash of considerable width; and the deeper it is required, the wider it must be at the top. This involves great waste of timber and physical effort; and, after all, the cut is not, at the best of times, very even or regular. Timber can be divided in a neat and comparatively easy manner by the *saw.**

The saw consists essentially of a thin plate—best of steel—having a line of small *chisels* or *teeth*, formed in succession on one of its edges, and furnished with means for moving it in the direction of the teeth while they are pressed against the material to be sawn.

Each tooth, one after the other, cuts away a shaving or chip; and as all the teeth follow in

* The saw is of great antiquity, and is said to be represented on Egyptian monuments, owing its origin to the use of a snake's jaw-bone for dividing small pieces of wood.

line, they form a narrow slit, or "kerf," of the same width as the teeth occupy.

While the motion is continued, the kerf is prolonged, or deepened, and the plate or *blade*, as it is usually termed, passes into the kerf to allow the teeth to follow their work.

Saws are used for cutting various substances, but it will be our business to consider them mainly as applied to cutting timber for underground work.

The best saw-blades are made of *cast*-steel. *Shear*-steel makes fair blades. They should be thin, and as stiff as possible, with sufficient elasticity to regain their truth after bending. The blade is made as thin as possible, consistent with giving it the necessary stiffness, in order to secure a *narrow* kerf, thereby to save timber and useless expenditure of power in sawing.

Fig. 120 represents a "hand saw," which is frequently a very useful tool to miners. 26 to 28 inches is a convenient length for the blade. The cost of such a saw, of the best cast-steel quality, is from 4*s*. 6*d*. to 5*s*. at ironmongers' shops.

Fig. 121 is a sketch of the "crosscut saw." This is a very serviceable tool for dealing with heavy timber. Two persons are required to use it. A blade of from 4 to 5½ feet in length is a useful size, and when made of good cast-steel, the

cost may be taken as ranging from 10*s*. to 13*s*. each.

Fig. 122 shows the blade of a "pit saw." This saw is of great utility in converting large quantities of rough timber into true pieces, planks, or boards. It is used by two persons—one standing above the other. The top sawyer's handle, called the "tiller," is illustrated by Fig. 123; and the "pit saw box," the bottom sawyer's handle, which is made entirely of wood, by Fig. 124. For the latter purpose, Fig. 125 shows one which is made partly of iron.

Although the pit saw is seldom used by mine timber men, it is advantageous if they are able to work with it in some cases of emergency. In cases of rareness it finds its way underground, and a capital *saw-pit* can be made by stoping out the floor of a level.

A pit saw blade about 7 feet long is a useful size, and if made of best cast-steel, it would cost about 17*s*. to 20*s*

Saws of an inferior quality, known as *German* steel, can be bought for about one-sixth less.

As much as possible of the sawing required at mines is best done at the surface by men specially accustomed to the work; but often a miner's calling demands that he should be able to saw for himself, underground as well as above.

The teeth of saws are sharpened by fine files—generally *second-cut single,* or *smooth,* or *dead-smooth* float-cut, according to the fineness required. Three-square files * are used for sharpening *hand* and *crosscut* saws, and *half-round* or *round gulleting* files are used for *pit* saws. For hand-saw files, serviceable lengths are 6 or 7 inches, and they cost 6*d.* to 7*d.* each, or less if bought in quantities.

After the teeth are filed, a little raggedness is left on their outside edges. This should be removed by laying the saw down on its side on some flat surface, and rubbing a long *hone,* or fine grit-stone, along the sides of the teeth—thus giving the tips smooth and keen edges and points, and reducing any prominences.

Of all saws, the *hand* saw is most useful to miners. The handle—made of wood, and fixed on the wide end of the blade—is generally more slender and gracefully formed than the one we have shown; but a plain, strong, and comfortable handle is what is really required.

Properly there are two sorts of hand saws, differing chiefly in the shape of the teeth. One is used for cutting *with* the grain of the wood, and is called a "*rip saw;*" and the other is adapted for cutting *across* the grain, and is called a "*crosscut*

* These files are called *blunt* when the corners are parallel and *taper* when they tend to a point.

hand saw." Hand saws are made to cut one way only—by *pushing*—so that the thinness of the blade requires that it should be made *wide* to give it sufficient stiffness to resist *buckling,* and to afford room for sharpening the teeth, which gradually wear away by filing.

When a *curved* cut is required, saw-blades must be *narrow,* in proportion to the radius of the curve and the width of the kerf, so that they may form a tangent to the circular cut. This circumstance requires that the blade should be strained—to give it stiffness—in a *frame,* sometimes called a "saw bow," in which it is tightened by a screw, or Spanish winch arrangement.

Four points, relating to the teeth of saws, deserve consideration, viz. :—

1st. Setting.

2nd. Bevelling.

3rd. Angle of the cutting edge.

4th. Size of the teeth.

We shall find it most convenient to take them in this order.

1st. *Setting.*—The teeth of a saw have to be arranged to cut a kerf somewhat wider than the thickness of the blade, to allow it to move freely between the sides of the kerf, without wasting the power applied by having to overcome much friction. This object is sometimes attained by grinding

the blade of the saw thinner behind the teeth. Oftener, however, the same purpose is answered by bending every *other* tooth sideways in one direction, and every intervening tooth in the opposite direction. This operation is called "setting," and it explains the spreading out of the teeth noticeable in Fig. 126, which shows the end of a saw-blade as seen by looking along the line of teeth.

As the teeth thus bent, or *set*, would cut a kerf equal in width to the space between the dotted lines, the blade would have plenty of liberty to pass between.

The *setting* of the teeth requires care. It should be done throughout with as much *uniformity* as possible. A wrench having slits in it to fit over the teeth, and called a "saw set," is generally used for bending the teeth, each succeeding tooth being inclined in an opposite direction. Many persons require long practice to do this well. There are some mechanical contrivances to be obtained for setting saws by hammer blows, which greatly simplify the work. Very *wet* or "green" wood, being a little spongy, requires *more* set on the saw used for cutting it than timber which is *dry*. For the same reason, the sawing of *soft* wood requires a little *more* set than *hard* wood. The set should be only just enough to permit the blade to move easily in the

kerf. Whenever the blade *jams* in the kerf, if not buckled, then the *set* is not sufficient.

2nd. *Bevelling.*—Instead of the tips of saw teeth terminating in a narrow *chisel-edge*, they can be made to terminate in a sharp *point* by what is termed "bevelling," and the *front* or *back* of each tooth may partake of a knife edge on the outer side by the same operation.

This is done by holding the file, used for sharpening the teeth, *obliquely* to the plane of the saw plate, instead of at *right angles* to it, so that the edges of the teeth become *bevelled* as shown in Fig. 127, and consequently, by looking at the end of the blade, the line of teeth is seen to form two rows of *points*, as shown by Fig. 128.

Bevelling, then, makes the tips of the teeth more *incisory*, and enables them to score into the wood on each side of the kerf. The more obliquely the file is held to the line of teeth, the more the bevel will be, and the more acute will be the points of the teeth. The *acuteness* of the points can be influenced by the amount of bevel on the *backs* of the teeth independently of the bevel on the *front* edges, but in the crosscut saw both edges are alike.

The proper bevel to be adopted depends mainly upon the angle at which the line of teeth has to intersect the grain of the wood to be sawn.

The advantage of bevelling applies principally to saws for *cross* cutting, because in this kind of work the fibre has to be *severed* on each side of the kerf, and the teeth should have *acute* points, in order that they may easily score down the sides of the kerf, whereupon, through the fibre being completely cut off in two places, the intermediate bits will crumble out as "dust" by contact with the moving teeth.

The more acute the points can reasonably be made for crosscutting any sort of wood, the better for sawing; but with hard wood much bevel would make the points too slender to stand well.

For crosscut hand saws, one thing to avoid is filing *too much* bevel on the *front* edges of the teeth. When bevelled very much the teeth do not carry out the dust well, but they *turn* it over alternately from side to side of the kerf, so that it gets *jammed* in and binds the saw. Fig. 129 shows a plan of a horizontal saw cut, showing two teeth in it, and supposing the back of the saw to be removed. It will be noticed that, at *a*, the bevel fronts of these teeth act like the breast of a ploughshare by turning the dust *aside*, but the square-front teeth, shown at *b*, are better adapted for carrying the dust *forward* that it may be cleared out of the kerf. The difference between

the bevel filed on the *back* and on the *front* of a tooth is not sufficiently understood. Many singular opinions respecting much bevel being a disadvantage for crosscutting hard wood on account of the teeth *scoring too easily*, and cutting *deeper* chips than they can *carry out*, probably owe their origin to an oversight of the difference just referred to.*

Now, for *rip* saws hardly any bevel is required, since the fibres part easily in longitudinal direction, while the *dust*, instead of being *crumbled*, is *shaved* off, as will be seen hereafter. A *slight* bevel is generally allowed, as the grain of the wood does not always run exactly in line with the saw cut.

3rd. *Angle of the cutting edge.*—This refers to the *inclination* of the front edge of the tooth, and it is sometimes spoken of as the *pitch*.

In the case of rip saws, the angle of the cutting edge is a very important point, because each tooth ought to be well adapted to the paring off of small *shavings*. Reference to Fig. 130 will show that the teeth at the lower part are formed suitable for paring the shavings easily, while the upper teeth can only drag or *jag* out little bits,

* The crosscut saw, shown by Fig. 121, must have the same bevel filed on the front as on the back of the teeth, because it cuts both ways.

at the expense of much waste of power. Parrot bill and gullet teeth are not used for hand saws.

In sawing timber, one tooth cuts a shaving or carries out a bit of "dust" behind another, and this allows the blade to progress in its course or to "advance" by deepening the kerf continuously. The *rate* of advance depends upon the thickness of the shaving cut by each tooth, as will appear plain on reference to Fig. 130, where the thickness of the shavings, represented by dotted lines, is a little exaggerated for the sake of clearness.

When the teeth are sawing, the line of motion of each tooth is parallel to *a*, *b*, and not to the line of tips, *b*, *c*. By the time the tooth *b* has cut along and down to *a*, other teeth, above *b*, will have cut the upper part of the kerf back to *d*, so that the face of the kerf always remains parallel to *a*, *d*—the direction maintained by the line of tips.

The thicker the shavings are, the greater will be the angle contained between the line of tips and *a*, *b*, and the quicker will be the rate of advance. As in the case of any cutting tool, the thickness of the parings, or the penetration of the edge, is governed not entirely by the angle of the edge, but largely by the pressure applied; and so it is with the teeth of a saw. The total pressure applied to a saw may be said to be divided about equally on each of the teeth which take bearing.

If, then, the piece to be sawn is very thick or deep in the direction of the face of the kerf, there will be more teeth bearing, and consequently less pressure per tooth, so that thinner shavings will be cut than when the piece is thin or shallow. In sawing such a thin piece, all the pressure on the saw being divided on few teeth causes them to penetrate deeply and cut coarse shavings or dust; hence the saw advances rapidly. This explains how, with the same saw, the *dust* from a *deep-faced* cut is *finer* than from a *shallow-faced* one.

Although the teeth *x*, Fig. 130, would be a better form for a *rip* saw than the teeth *z*, they would not answer as well for a *crosscut* saw, because, as it will be remembered, the teeth of a crosscut saw are not required to *pare* shavings so much as to *score* through the fibre on both sides of the kerf. It also appears plain that the tooth shown by Fig. 131, if moved in the direction of the arrow over a piece of wood, is not adapted to make such a smooth and clean incision as the dog-tooth shown in Fig. 132.*

If, however, the teeth of a crosscut hand saw are made quite of the dog-tooth shape, they will often be found to have too much tendency to *ride*

* Scribing tools are, for a similar reason, sharpened with diagonal edges, to enable them to scribe into wood without causing raggedness.

over the dust, so that the fronts of the teeth require to be a little more upright, as at *z*, Fig. 130, to properly clear the kerf.

The crosscut saw (Fig. 121), having to cut both ways, has *peg*-teeth, which are filed so that the cutting edges are identical in shape for both strokes, as previously observed with reference to the *bevel*. The result is that, although the angle is favourable for scoring easily, it is not the most favourable for clearing out the dust either way, unless made moderately upright with slight bevel.

To remedy this, Tuttle's patent crosscut saw has been introduced. The novelty is in the shape of the teeth, a few of which are represented by Fig. 133, which shows a piece of the edge of the blade, supposed to be broken off with a few teeth on it. The dog-teeth are bevelled for scoring easily, whereas the intermediate *hook*-teeth are filed with square edges, and shaped well for clearing out the dust.

This saw is reputed to do its work *very* rapidly. The teeth are rather slender, which is no recommendation for underground work; and after repeated sharpening, the hooks, instead of being preserved, will file out altogether, thereby necessitating the formation of a new set of teeth.

4th. *Size of teeth.*—After deciding the shape and the *pitch* or cutting edge of saw teeth to the

best advantage for strength, efficiency, and convenience of sharpening, their size depends on four considerations, viz. :—1st, the nature of the wood to be sawn; 2nd, the direction of the cut; 3rd, the pressure to be applied on the saw, and the sharpness of the teeth; 4th, the depth of the cut.

When a saw is in use, every *space* between the teeth becomes a store-room for the chips, shavings, or dust, until it passes through the wood, whereupon the dust falls out. It is an advantage, in some respects, to have the greatest number of teeth which can be consistently formed in a saw for doing the work, but if the teeth are numerous they are necessarily narrow, and the spaces between them are small. These spaces have to serve as repositories for the dust, and in case of their not being sufficiently large, the dust, by accumulating, gets *compressed* in them, and keeps the teeth from advancing with good effect.

Now spaces cannot be enlarged between teeth of given distance apart without weakening the latter; therefore, when large spaces are required, it necessitates having fewer teeth.

The softer the wood, the coarser the teeth are required, to afford ample intermediate space for holding the dust, which collects more rapidly from soft wood than from hard-cutting sorts.

For a similar reason, as wood cuts more easily

with than *across* the grain, the teeth of a *rip* saw should be coarser than are needed for a *crosscut* saw.

As increased pressure on the saw, or sharper teeth, make it cut dust more rapidly, it is clear that the greater the pressure and sharpness, the larger the store-room or space should be. Saws worked by two persons, on account of having more pressure applied to them, require coarser teeth than saws worked by one individual; and sometimes good cutting saws get *crammed* or choked by putting an excess of pressure upon them.

In a deep or long kerf a great many teeth pare at once, and under a given pressure the shavings or chips cut are thinner than would come from a shallow or short kerf, but the whole *volume* of dust cut by each tooth throughout the long kerf is generally greater than would be produced in a short one; and hence the deeper kerf needs the larger store-room or space between the teeth.

For hand saws the following are the numbers of teeth per inch suitable for the different sorts of wood:—

Soft wood	crosscut	5 teeth per inch	6 points
Medium ,,	,,	7 ,, ,,	8 ,,
Hard ,,	,,	9 ,, ,,	10 ,,
Soft wood	rip	3 ,, ,,	4 ,,
Medium ,,	,,	4 ,, ,,	5 ,,
Hard ,,	,,	5 ,, ,,	6 ,,

Saws should be selected to suit the work which they are intended chiefly to do—in some mines cutting larch, spruce, &c., in others chestnut or beech, and sometimes chiefly oak.

Before a saw can be expected to cut with facility, the plate should be true and smooth, and every tooth should be formed to do its work with as little expenditure of power as possible. Moreover, the kerf ought to be as narrow as practicable with giving the blade sufficient freedom. The teeth should stand in regular order, and should be uniformly filed; for if only one tooth projects beyond the rest, or is too prominent sideways, it encounters unnecessary work, and interferes with the duty of others, while a too retired tooth does no service whatever, but rather overburdens the adjoining ones.

In *hand* and *pit* saws the line of tips should be straight, or very slightly "bellied." If the tips get very irregular they had better be filed off until all project equally, and then every tooth can be sharpened again, care being taken to stop the filing immediately the tip is formed, for if continued further it shortens the tooth. If by any accident a tooth becomes too short, it should be allowed to remain so until, from wear, all the rest of the teeth get filed down to fall in line with it.

No good can be done by filing down a *few* teeth adjoining the short one.

When a hand saw is held vertically, a piece of fine cotton suspending a weight, and fastened between the top pair of teeth, will hang like a plumb-line, and ought to lie quite straight in the bottom of the valley formed by the bevel and set of the teeth, from top to bottom of the saw.

"Stone saws," which are commonly of the double-hand crosscut pattern, but with a straight back to the blade, like a Russian crosscut saw, are used by miners in certain instances for cutting soft minerals, such as rock-salt, freestone, &c. They are furnished with dog-teeth, which are filed without any bevel. A common size is $\frac{5}{8}$ of an inch from point to point. The blades of stone saws are commonly nearly $\frac{1}{8}$ of an inch thick; and, for large sizes, still thicker. Sometimes the difference between the thickness of the blade at the back and at the front is sufficient to give proper clearance without any set on the teeth. Setting of the teeth may be performed by laying them on an iron block, so that the points overhang a little more than $\frac{1}{8}$ of an inch, and then giving every other tooth a smart tap with a hammer having about a 1lb. head, with a narrow pane. The intermediate teeth are set in

the same manner, after turning the blade to lie on the reverse side. This mode of setting bends the teeth only near their tips, and produces a small flattened surface where contact with the hammer occurs on one side or the other of each tooth—slightly diminishing the thickness at the points. It is a method preferred by many to the use of a saw set, which they consider increases the liability to break teeth by straining them at the roots, especially as the saws referred to are of a rather hard temper for wearing well in use. In cutting dry freestone, the dust from sawing clears out from the kerf freely; but in dealing with damp stone, though softer, the dust often clogs, unless water is passed into the kerf in sufficient quantity to convert the abraded stone into a liquid sludge capable of being worked out by the movement of the saw. The handles of stone saws used for freestone cutting are usually from 18 inches to 2 feet in length. Sometimes they are furnished with ferrules like file handles, suited for driving over tangs,—called "stearts,"—riveted to the blade. More generally, however, the handles fit into sockets, after the manner shown in Fig. 121—a plan which is better for convenience of changing, or renewing, when needed. The blade of a 7-feet stone saw, about 11 inches deep at the bellied part, can be procured for about 21*s*.

At the Box stone-quarries "one-handled saws" are in constant use for cutting off blocks of stone from their natural positions, in a manner which is far superior to the former practice of doing so with jadding tools, which required more time and caused greater waste of stone—no trifling considerations.* The length of these saws is, of course, governed by the dimensions of the blocks required. It is seldom less than 5 feet, but sometimes more than double that length. The end at which the handle is placed is called the "heel," and it is less in depth than the other extremity—the "toe" or "point," which encounters greater wear in use, chiefly by a tendency of the saw to weigh upon that part. When new, the teeth range in a straight line, continuing quite out to the point. The back is also straight, and the blade regularly increases in depth from its heel until near the point where the back is curved off, as a quadrant, to meet the line of teeth at the toe end. By use, the wear of teeth near the toe, and frequent filing, cause them to deviate from a straight line, and to curve upwards to meet the back. Small sizes of such saw-blades when new

* Jadding tools are still used for holing over the upper sides of the blocks to be detached, in order that room may be provided for the saws to commence working for the vertical *side* and *back* cuts.

are about 10 inches deep at the heel, and 12 inches at the toe, but after continued wear the toe becomes much less in depth than the heel. Socket handles are usually employed, on account of being handiest for changing. When beginning a cut close under the overlying strata or roof of the so-called quarry, the handle has to be removed and driven in at the under side of the socket, in order to clear the roof and enable a sawyer to take hold below the socket-piece. When socket-pieces are fitted to saws at the quarries, smiths put them on the blade in a red-hot state, and the holes are not punched through the steel blade until it has become a little heated to reduce any risk of cracking. The three-square files used for sharpening are about 10 inches long, and cost 9*s.* per dozen or thereabout. Some proprietors of these quarries—producing Bath stone, so much in request for architectural purposes—order their saws by *tons.* This will convey some idea of the extent to which saws are employed by those engaged in this branch of industry.

Proficient saw-filing, although in some cases involving many considerations, is an art nevertheless easily acquired by any person of ordinary intelligence. When a miner has much timbering to do, his work will be greatly facilitated if he can command the use of a good saw, and he will soon

experience the advantage of keeping it in efficient order.

A good saw is a most serviceable cutting instrument, and, by attending to the points which have been noticed, miners will be able to make favourable use of its capabilities, and to fettle their saws for themselves better than many who profess to understand it.

It may be noticed that the teeth of a saw, especially if worked by machinery, can become so heated by work as to reduce their temper, at the same time causing, by expansion, local or general buckling of the blade or plate.

MISCELLANEOUS TOOLS.

We now enter upon a very diversified chapter.

Fig. 134 represents a "scraper," used for cleaning out, at intervals, the pulverized matter from bore-holes, so that it may not prevent the bit from operating freely on the solid rock. The pulverized matter is called *boring-dust* or *meal*, and when it has been wetted to facilitate boring, it is called *sludge*. If much of it is allowed to accumulate in a hole, it materially interferes with the effectiveness of borers. Scrapers are usually made of light rod-iron—$\frac{1}{4}$ to $\frac{1}{2}$ inch diameter—sufficiently long to reach to the bottom of the hole intended to be cleaned, and having the scraping end flattened out nearly as large as the diameter of the bore-hole, so that it may be turned up at about right angles to the rod for forming a small circular platform, on which the boring-dust may be collected and removed. When the scraper is put into a bore-hole and slightly turned round, the dust, or sludge, accumulates on the platform, and can be

drawn out a little at a time until it is sufficiently cleared away. From ascending bore-holes, with a rapid upward inclination, the dust falls out of its own accord; but the advantage of thus having the end of the hole constantly cleared is countervailed by the disadvantage of there being no means of keeping water in the hole while boring. Fig. 135 shows a double scraper, with a mushroom stage on one end. Fig. 136 shows a scraper having a sliding-rod, so that it can be lengthened for long or deep holes. Fig. 137 shows a scraper with a "drag-twist" on one end of the rod. The drag is used for cleaning out holes before putting in the charge. In this case a wisp of hay is pushed into the hole, and the drag is afterwards put in and turned around, so that the hay, becoming entangled, gets turned around also, and sweeps the sides of the hole. Upon withdrawing the drag, the hay comes out in one wad, and carries the sludge with it. Fig. 138 shows a scraper made out of light flat iron, with a "loop-drag" on one end, used also for cleaning holes by passing a bit of rag or tow through the loop, so that it may be put into the hole to sweep out the sludge.

Fig. 139 represents a scraper having a powder charger on one end of the rod, forming a "scoop" or "spoon" for conveying the powder to the

ends of horizontal holes. The scoop is also used, in some instances, for clearing out the boring-dust.

Drags and spoons are often made as separate tools. These, and ordinary scrapers, cost from 4*d*. to 6*d*. per lb.

The "swab-stick," represented by Fig. 140, is habitually used by many miners for clearing bore-holes. It is simply a piece of stick—generally deal—small enough to enter the hole, and long enough to reach to the bottom, with its fibre at one end spread out by bruising to form a stumpy sort of brush, called the "swab." When this is put into the bore-hole, the sludge passes by the fibrous swab, which, when it reaches the extremity of the hole, can be spread by pressure so as to touch the sides all round; and when it is withdrawn, it sweeps out the sludge before it. Repeating this operation a few times makes the hole tolerably clean, and by throwing a little dust, at the latter part of the operation, into the hole, the moisture is absorbed thereby, and the sludge dried up. Any grains of powder adhering to the side of the hole after charging are removed by damping the swab in water.* Another contrivance also used for clearing bore-holes is the "sludger," represented

* When a borer-bit breaks in the hole, the broken piece can often be extracted by hammering down the swab-stick upon it so as to embed it in the swab.

by Fig. 141. It consists of a long cylinder—ordinarily a piece of wrought-iron gas-pipe—for reaching into the hole, furnished with a small rod of iron to work inside, having a bow handle at one end, and a drag-twist at the other. A bit of hemp or tow is wound around the twist, to form a kind of piston for working within the tube. When this sludger is placed in a descending hole, upon drawing up the piston-rod it sucks the sludge up into the tube, and by rapidly withdrawing the whole apparatus, the sludge can be squirted away outside by pushing the rod back again. The hole will be properly cleared by repeating the operation a few times. There is no valve at the bottom of this sludger, which is seldom made of a tube above three-quarters of an inch diameter inside, so that it is suitable for use only in bore-holes of ordinary size for blasting.

In cases of deep bore-holes, as for wells or exploratory purposes, Fig. 142 shows a section of a sludger or "scoop" sometimes employed, and dropped down into the hole on the end of a rope, chain, or the rods. By jerking the sludger on the bottom of the hole, the sludge raises the valve at the bottom of the cylinder, and enters. It soon becomes laden with sludge, and is then drawn to the top, the valve at the bottom resting on its seating, and preventing the contents from running

out. The same kind of sludger is also used for clearing bore-holes through running sand. The common trap-clack, or conical valve, is sometimes fitted at the bottom. A butterfly-valve, or an ordinary ball or shot valve, is also used in some instances.*

Mr. Mather, who employs flat wire ropes instead of rods for deep boring, uses a sludger which is fitted with an inside piston for producing a partial vacuum above the bottom valve, in order to suck the sludge into the cylinder upon the same principle as in Fig. 141, with the addition of a bottom valve. The tool shown by Fig. 20 is occasionally used for removing boring-dust or sludge from the bottoms of deep holes.

Figs. 143 and 144 represent ordinary forms of "clay-irons" used for forcing clay into the joints and crevices around watery holes, in order to make them dry, and fit for using naked powder, which is more effective and cheaper than when enclosed in cartridges or pitch-bags. The clay-iron is a round bar of iron (called the "shaft") a little smaller in diameter than the bore-hole, furnished with a broad top (called the "head") for striking upon. Some provision is necessary for turning the shaft around its axis, &c. This is

* Leather or india-rubber valves are said to hold tighter than metallic valves, which are sometimes trigged with grit.

usually done by a lever, shown at *a*, which is put into an eye formed through the head of the clay-iron; but the one illustrated by Fig. 145 has a square head for being turned by a spanner or wrench, *c*.

After a wet hole is charged with some tough clay, the shaft of a clay-iron is driven through it by a sledge, and this, acting like a wedge, forces the clay into the crevices on all sides. The shaft is then turned and gradually drawn out. Sometimes the entrance of water is thereby stopped, and the hole remains quite dry after the first attempt, but it may require several repetitions, and in some instances it cannot be made to succeed at all, either from the rock being too open or cavernous, or from the water acting with great pressure—in some instances sufficient to make the clay-iron rebound after each blow of the sledge, and to force it completely out of the hole.

Clay-irons have to endure a good deal of hammering on the *head;* therefore this part is usually made very stout on account of the wear. Those with an *eye* are most convenient for drawing out. The shaft should be smooth, and should taper a little to conduce to withdrawing, but the bottom of the hole will be too much contracted unless the taper be very slight. Miners accustomed to

driving through watery strata, often attach importance to the clay-iron, and it is easy to conceive why so, if we remember how frequently it enables them to stop back all water running into a bore-hole, and thereby provide a dry receptacle for the charge.

Ordinary clay-irons cost about 3*d*. per lb.

When the heads wear down near the eye, they should be sent in good time to the smith's shop to have a new piece welded on.

Fig. 146 represents a "shooting-needle" or "nail," made of round rod-iron, and used for forming a "vent-hole" or small passage through the *tamping* which confines the charge in a bore-hole for blasting. The passage is used for admitting a *mote* or *squib* to enable the charge to be ignited. When the charge is put into the hole, the needle is laid in with its point penetrating the explosive compound. The tamping is next rammed or stemmed in, and the needle is afterwards drawn out, which is often facilitated by putting an iron bar through the bow handle, and striking the bar with a hammer. When it is withdrawn, a small passage or channel remains, like a long touch-hole, leading into the charge. A *rush*, *reed*, *paper*, or *quill* tube, filled with a "priming" of gunpowder, and termed a "match," "squib," "mote," or "train," is next passed

through the touch-hole into the charge. Subsequently, a "smift," which is variously made of either a bit of touch-wood, touch-paper, greased candle-wick or paper, or cotton dipped in molten sulphur, is attached by a bit of grease or clay to the outside end of the *train*. At the extremity farthest from the train, this smift is ignited, after it has been arranged to burn long enough to give the miner sufficient time to retire before it kindles the top of the train, which then instantly conveys the fire to the charge and explodes it. This primitive method of exploding charges is still in considerable use. Many casualties have occurred by accidentally lighting the *train* instead of the *smift*, whereupon the explosion occurs before the miner has any chance to get away. Such accidents may now and then be traced to carelessness in adjusting the smift in places where a current of air occurs, by thoughtlessly putting it on the windward side. Then, on attempting to light the proper end of the smift by applying a flame, the latter may be so deflected by the draught as to prematurely ignite the squib. Again, in working some parts of coal measures a little fire-damp will sometimes escape unawares through or about the bore-hole, and lurk about the smift. On bringing a naked light into contact with the smift, the gas explodes and forms a small cloud of fire sur-

rounding the priming, which thereby fires the charge without warning.*

Untold accidents have also occurred by drawing out the needle, in consequence of sparks being produced by its rubbing against any silicious matter in the tamping, whereupon the charge, or any powder in stray grains † adhering to the sides of the hole, becomes ignited, and disastrous consequences succeed. For greater safety the needle is often greased and covered by a casing of paper. To better avoid danger, *copper* needles are used. Being more liable to bend than iron needles, they are often made stouter. Fig. 147 shows a copper needle with an iron handle heated and shrunk, or brazed on. It is about the best sort of needle that can be used.

Fig. 148 represents a "pricker," used instead of a needle, for being driven through the tamping with a hammer after the tamping is finished. It is next drawn out, something like a needle, and leaves a perforation for putting in the train. The pricker is more dangerous to use than the needle. If made of copper, it is too easily bent.

* By employing *safety-fuse*—to be noticed shortly—instead of the common squib, the risk alluded to is, so far, removed.

† This danger is avoided by using powder in cartridges. Miners' common objection to cartridges is, that the powder space below the tamping is not so completely filled as when naked powder is used, and that the air spaces around the cartridge act as cushions against the force of the charge.

Shooting-needles and prickers are usually from 18 inches to 3 feet long, and from $\frac{1}{4}$ to $\frac{3}{4}$ inch diameter, tapering almost regularly to the point. When made of iron they are worth from 4*d.* to 6*d.* per lb., and if copper, about 1*s.* 4*d.* per lb.

In some continental mines a much safer plan is adopted—that of putting a casing of large reeds around the needle. This keeps it away from all grains of powder and tamping; and, after the needle is drawn out, the reed casing remains behind, to form a passage for the train.

In many places the use of needles and prickers has been entirely abandoned in favour of *safety-fuse*, which is sold in coils of 24-feet lengths, resembling a coil of plain cord. The fuse is made ordinarily of tape, hemp-cord, yarn, gutta-percha, or metallic covering, called the "countering," which forms a small tube for containing a continuous core of slow-burning powder-composition or priming. A piece of this fuse is put into the hole instead of a needle, and the tamping is rammed in afterwards, one end of the fuse being outside of the hole, and the other end penetrating the charge. When the outside end is ignited, the fuse serves as a *slow* train, burning at the rate of about two feet per minute, and it can be cut off sufficiently long to give the miner time to retire in security after lighting it.

The main dangers with fuse are, the risk of its being pressed into crevices and bruised, or cut through with sharp angular stones in the tamping, and moreover of there being a defect in the continuity of the powder core, or of its becoming damp and wetted through in the hole, in all of which cases there is danger of the fuse *hanging fire,* and, by smouldering, it may rekindle the unburnt portion, and unexpectedly explode the charge after a long interval. We have known this happen after fuse has hung fire nearly an hour, but it almost exclusively applies to fuse of inferior quality, which ought never to be used. With good fuse, and especially when covered with a waterproof coating of gutta-percha, and having one or two touch-threads running throughout the middle of the core, hardly any danger need be apprehended from this source if only ordinary precaution be observed. Reliable safety-fuse can be obtained in most mining localities at an inexpensive rate; and wherever this is the case, needles and prickers, with their concomitant dangers, should be regarded as things of the past.

The method of firing charges by electricity is calculated to surpass all others for perfect safety.

Fig. 149 represents the ordinary "tamping bar," used for driving some suitable substance,

called "tamping," into blasting-holes after the charge has been put in, in order that the force of the explosion may be pent up and act against the side intended to be removed. The tamping end of the bar is grooved on one side, to admit of its clearing the needle or fuse lying along the side of the hole. The other end is left plain for the hand, or for being struck with a hammer.

When tamping can be put in sufficiently tight by simply ramming the bar against it with the hand, then, instead of leaving one end plain for being struck—ramming by sledge blows being dangerous in the estimation of many—another tamping end is sometimes formed, as indicated by the dotted lines on Fig. 149.

Tamping bars are commonly made of iron, and many accidents have happened in consequence of their striking fire against quartzose matter which they have come in contact with. To prevent such accidents, tamping bars are sometimes faced with *copper*, as at *a*, Fig. 150. This tamping bar has a *bit* at one end for boring holes in any frangible mineral, by impetus given with the hand. Another form of tamping-end, sometimes faced with copper, is shown at *b*, Fig. 151.

Bronze facings or tips, as shown at *c*, Fig. 151, are also used to avoid the danger of striking fire.

Occasionally these tools are made wholly of

copper or bronze. Bronze has the advantage of being harder and stiffer than copper.

Iron tamping bars cost from 2*d.* to 3*d.* per lb.; with copper or bronze tips, from 6*d.* to 9*d.* per lb.; and copper or bronze altogether, from 1*s.* to 1*s.* 6*d.* per lb.

Many different persuasions are to be met with regarding the material best suited for the purpose of tamping, or, as it is sometimes called, stemming. Baked or sun-dried clay makes tamping of very good quality. Powdered brick answers the purpose very well. The boring-dust out of dry rising holes—generally collected on the plate of a shovel—in many instances makes excellent tamping. It is not uncommon to find an accumulation of binding argillaceous ground, possessing good properties for tamping, occur in mines; then the miners dig it out as required. All tamping should be selected to contain no particles likely to strike fire; but the cause of such casualty may lie in the *sides* of the *hole* itself, and it is surprising that this is so much lost sight of.

Under these circumstances is seen the advisability of using bronze or copper-faced tamping bars, and of not hammering violently on the tamping until a little of it has first been gently pressed down to cover over the charge, because the

earlier blows on the tamping bar are most dangerous in event of any spark occurring. A little wadding, tow, paper, or a wooden plug, is sometimes put to lie against the charge before any tamping is placed in the hole.

It is generally troublesome work to get tamping up into *rising* holes, having a rapid upward inclination.

The hand sludger is occasionally made to assist, by putting a little tamping into one end of the tube, which is then placed in the hole so that the tamping can be forced out by the piston-rod.

Fig. 152 shows a "tamping case," which may be used to greater advantage in such instances. It is made of copper or brass, with a long handle, and is passed over the end of the tamping bar. When this is done, the case—which has a *slit* for clearing the fuse—is filled with tamping, and pushed up into the bore-hole. The case is next drawn back, so as to leave the tamping in front of the bar, by which it can be pressed or hammered up.

We have found *plaster-of-paris*, used in a plastic or semi-fluid state, make excellent tamping, first putting a little dry plaster against the charge. The plaster costs only about 2*s.* per cwt. in large lots. It sets quickly, expands slightly by setting, and requires no ramming, as it can be poured

into downward holes, and can be put, in a plastic state, into rising holes, with a light copper scraper.

Fig. 153 shows a funnelled "powder-charger," best made of copper. The powder is received by the conical part, and passes through the pipe —which may be screwed together in several lengths—to the bottom of the hole without hanging about the sides, thus avoiding a well-known danger. A long stick fits inside for pushing forward the powder when necessary. A common saucepan handle is often used for charging.

Figs. 154 to 158 show ordinary forms of "gads," used for working jointy or cellular ground, or rock which has been fissured by blasting. They are also much used for wedging down hard coal after undercutting. Some apply the term *gad* to these tools when they have a *point*, and when they have a *chisel* edge the term *wedge* is used.

Figs. 159 to 163 represent other forms of gads and wedges used in various mining operations. There is great multiplicity in the sizes of gads, the length often varying from 3 inches to 2 feet. Six inches to 1 foot are useful lengths.

They are sometimes made of wrought-iron, with a tongue of steel welded in to form a point, and sometimes the striking-end is faced with steel. Very often, for the sake of durability, they are made of steel altogether. Cast-steel borers, which

have been worn short, are often used for making gads in hard-ground mines, and, in order to stand well, they should be carefully annealed, as they are submitted to cross strains by side blows from the sledge, for the purpose of loosening them or the adjacent rock.

Fig. 164 represents a Saxon gad, having near the middle an eye, which is used by Saxon miners for threading several gads together on a sling, to facilitate carrying them to and from work, or for putting in a light helve to form a temporary handle. This has but little recommendation to a British miner, considering that the eye weakens the gad. Fig. 165 shows a gad used by Mexican miners. It is round in cross section.

In working some sorts of "jointy" or "vuggy" ground, gads are of great importance, and each miner sometimes carries over a dozen of them to his work daily. The best sort of gad for this purpose is made of *shear*-steel, and to cleave well it should approximate the shape of Fig. 154. It is generally about 1lb. weight, and 6 inches long by $1\frac{1}{4} \times \frac{5}{8}$, or $1 \times \frac{1}{2}$ inch, in the largest part, tapering to a point.

Iron gads with steel points are chiefly used in collieries. Their lengths range from 6 inches to 2 feet—a very common length being 12 inches, and weighing about 3lbs.—the greatest thickness

being about 1 inch, and the greatest breadth about $1\frac{3}{4}$ inches. These wedges resemble Figs. 154 and 155 in shape, and one smith with a striker can make about two and a half dozens per day. The collier's wedge-sledge, noticed on p. 66, is specially adapted for driving these wedges (as is often necessary) after their ends have gone in flush with the face, because the panes of the sledge are small enough to follow the wedges.

Steeled iron wedges cost from $2\frac{1}{2}$*d.* to 3*d.* per lb., and solid steel wedges from 4*d.* to 5*d.* per lb. Gads are usually blunted more than pick-points, and therefore they take a little longer time to sharpen. They are tempered in the same manner as picks. In some collieries the remnants of old iron wedges are collected in when new ones are supplied; and when sufficient numbers have been accumulated they are faggoted under a steam or other hammer into bars for new wedges.

Gads and wedges are very liable to get buried beneath the coal, rubbish, ore, or attle underground, unless carefully looked after. A great deal of steel often gets lost in this way, and it has been the chief reason for introducing into many mines the system of charging miners for all the steel they wear away or lose.

In some collieries, where wedges have to be driven into a yielding substance, or under a soft

top, a pair of thin plates, called "clamps," are first let into the ground, to afford a larger bearing when the wedge is driven between, as shown by Fig. 166.

The "plug and feather" arrangement, shown by Fig. 167, is very useful for wedging off large blocks of mineral. A hole is first bored, and after the two inverted wedges, *a*, *a*, with circular backs, are placed in it, the driving wedge, or plug, is driven between to detach the mass. Plugs and feathers lessen the friction of wedging. They are occasionally found useful for benching down long faces of coal, and are of constant use in some quarries for breaking off large pieces of stone, by arranging several of them along the line of intended fracture. In the Box stone-quarries, two iron wedges called "chips"—see *x*, Fig. 167—are used instead of the feathers, *a*, *a*, and are placed, with the thin edges outward, in a recess cut to receive them, so that a wedge may enter between.

It is to be hoped that the time is rapidly approaching when a very large part of the labour of driving gads and wedges will be superseded by the use of the excellent hydraulic machines now being introduced into collieries by Mr. J. Grafton Jones—well known in connection with his patent coal-cutting machinery—and other inventors.

These machines fit into holes previously bored for them, and they force down the coal by pistons or wedges acting under very great hydrostatic pressure, produced by a small hand-pump. The entire apparatus is quite portable, and where the occurrence of fire-damp in collieries makes the use of blasting-powder dangerous, these machines are destined to acquire a highly important substitutionary value. They are also applicable to many other branches of mining.

Mr. Davies, of Crumlin, has invented a machine to act upon the same principle, which, by a kind of flexible or jointed arrangement, will relieve itself of undue strains when at work, and accommodate itself to a crooked hole.

We now turn to notice some tools which are of special utility for advantageously working the well-known *Bathstone* at the quarries of Box (and other places), where, instead of removing the overburden, the quarrying is carried on underground, from adits or shafts, without disturbing the cultivated surface.

The "jadding pick," illustrated by Fig. 168, serves for cutting in long and deep holings, juds, or "jads," for the purpose of detaching large blocks of stone from their natural beds. The jads specified were formerly made in vertical as well as horizontal directions. Not long since,

however, an improved plan of *sawing* the vertical —or, as they are termed, "upright"—jads became generally adopted; but for working in the first cut horizontally in order to free one side—generally the top surface — of the block, and thereby to provide room for the saws afterwards to commence severing the other sides, nothing has superseded the use of jadding picks. They are made in sets of about three or four, with helves ranging from 3 to 5 and even 6 feet in length, so that the reach of the pick may be accommodated to the increased depth of the jad as it advances; and to enable the pick-point to catch properly under the same circumstances—besides having to reach into the corners—the head is not fixed on *square*, but *obliquely*, with the helve, as appears in Fig. 168. Wedges or iron dogs, driven in between the helve and the ends of the eye, assist in maintaining the proper obliquity of the head. That stem which forms an obtuse angle with the helve is called the "spreading" end, while the other is called the "coming" end; and the longer the handle—which implies the deeper the jad—the more the spreading is required to be, in order that the tip may have a chance to penetrate properly. For example, with a handle 5 feet long, a line square from helve, set off through the middle of the eye, would leave one tip about 2½

inches on the inner side of it, and the other tip about 2½ inches on the outer side. This is called 5 inches of spreading. With a helve of about 3¾ feet long the spreading would be, say, 3½ inches, and with a 3-feet helve about 1½ inches. The feature here particularised prevents one tip from being employed. It is only the spreading stem that is usable in the long-handled picks, since it is impossible to get the opposite tip to even touch the face of the jad.

The tips have chisel-edges ⅛th to $\frac{3}{16}$ths of an inch wide.* They are sharpened with a fine file, being bevelled off from the inner side, like the edge of a common adze. They are not sent to the smith's shop oftener than about once a fortnight, as the stone operated upon is very mild for working. For the shorter helves—say 3 feet—the heads may be 6 or 7lbs. weight; but for longer helves the weight usually diminishes to but little over half as much, seeing they are more fatiguing to use. Smiths in the locality supply 6lb. heads for about 3*s.* each, and re-steel for 4*d.* per tip.

* A pick of the same character, known in these quarries as a "holing pick," has its spreading-tip about ⅞ths of an inch wide, for cutting recesses just of the right size for receiving the two chips, *x*, Fig. 167, in cases of wedging. Sometimes, instead of this pick, the quarrymen prefer to use a "holing iron," which consists of a bar of 1-inch round iron, with a crutch handle at one end, and a steel chisel-edge about ⅞ths of an inch wide at the other extremity.

Horizontal jads are constantly being cut in these quarries close under the roof at the faces of the advancing headings, which are 15 feet wide and upwards, separated by pillars. After penetrating a depth of about 30 inches, a course of stone some 9 or 12 inches thick is "rapped in"—wedged down—from over the jad to increase its width, and then it is worked in another 30 inches, or so, deeper, making in all 5 feet, or sometimes more.

It is interesting to observe a Box quarryman cutting in a jad under the roof with a pick having a handle 5 or 6 feet long, and striking each blow with the nicest precision, thereby forming a large surface as even as the top of a table. Such a man will do an average day's work of 13 superficial feet of jadding, and with his long-handled pick will deal out about 26 effective blows per minute. Accustomed to the work, perhaps from boyhood, he can cut in very deep jads, not more than 4 inches wide, with surprising evenness.

For clearing out the corners of jads, or for widening them a little inwards, when they tend to cut out and get somewhat too narrow for the fair working of the pick, the jadding iron, Fig. 168A, is found a very serviceable tool. It is made about 7 feet long, out of, say, 1-inch round iron, and is furnished with a steel chisel-edge about $\frac{1}{4}$ inch wide, which is very effective in

chipping away the stone when driven against it by smartly-directed strokes. It is difficult to cut jads deeper than 5 or 6 feet with picks, but a depth of 7 feet and upwards can be more readily accomplished with the jadding iron, which is directed by hand so as to deal out a succession of strokes against the face of the jad. To penetrate this extra depth is sometimes very desirable for working out large blocks, or it may be for making the jad reach in to a suspected joint traversing the beds. Jadding irons were found to possess great adaptableness for cutting the upright jads formerly required. The jad was commenced with a pick, and continued with jadding irons until several feet deep. A man would thus do an average of 12 superficial feet of jadding per day, wasting only a width of about 4 inches of stone. Extravagant this may appear when compared with the kerf of a saw-cut; but the only marvel is that deep cuts so extremely narrow could be at all worked in by jadding, and that so evenly (as is testified by old pillars) that were it not for the tool marks the surfaces would be hardly distinguishable from those that are sawn. For deep horizontal cutting the jadding iron is greased to slide freely over a pick-helve, which is laid across under it. More than one bed at a time is worked in the quarries

under notice, and thus the workings are somewhat lofty. The sawn pillars are mostly rectangular and regular, but their position is to some extent regulated by the occurrence of joints, or disturbances, as well as any occasional difference in the quality of the stone at certain parts. When the face of any heading from which the stone is to be worked away has been properly jadded under the roof, the side saw-cuts are proceeded with. A narrow block between two vertical cuts —generally made at one side, unless some flaw in the stone or some question of sizes would dictate another place—is afterwards wedged up from one of the bedding-joints, for the purpose of enabling the sawyer to get forward for sawing the *back* cut parallel with the face. This being done, and the ends and top being free, the principal block easily parts from its lower bedding-joint, and is drawn out by a crab or crane.*

Blocks thus obtained from the working faces often need a little squaring or trimming, which is effected by the use of a "stone axe." The head of one is illustrated by Fig. 169. It is furnished

* It by no means appears palpable that some elements of this system of excavation might not be successfully applied for the working of hard coal, and other minerals which occur in thick deposits. Lewis holes are frequently used in these quarries for securing snatch-blocks to the pillars in order to draw out blocks of stone from the different headings.

with an oval handle from about 26 to 30 inches in length. The head is of iron, with steel inserted at each edge. Smiths in the neighbourhood supply them at about 10*d.* per lb., a 12lb. head costing 9*s.* or 10*s.* The edges are sharpened on a piece of pennant grit, and now and then they need to be *drawn out* by a smith, his common charge for doing so being 4*d.* They are tempered to about *brown* or *purple.*

In the same quarries the wedges employed with the chips, *x*, Fig. 167, are commonly about 18 inches long, in shape approaching that of Fig. 160, but with less taper from near the point to the striking-end, where the size is about 3 inches wide by 1½ inches thick.

What is termed a "driving iron," used for rapping or wedging down from over the jad, as before explained, is simply a bar of round iron about 1¾ inches diameter and 3 feet long, having a few inches at one end flattened out to a chisel shape for being driven like a wedge.

The sledges employed with these tools and for general purposes belong chiefly to the bully pattern, with heads varying from 8 to 20lbs., according to the use for which they are intended.

Passing from the class of quarrying tools which have engaged our notice, we may now glance at some for other purposes.

Figs. 170 and 170A represent two "pickers," and Fig. 170B represents a "poker." These tools are used in Saxony and in parts of Cornwall for working in jointy ground, and in some thin hard veins. They are very useful for getting between the sides of narrow clay joints, for clearing them out, to give side shots a better chance for blasting. Such tools are commonly employed in Saxony, but their use is, in this country, almost confined to the St. Just district. Some of the miners in that part use them very dexterously, and a St. Just miner can often be distinguished from his fellow-countrymen by a horny blister mark on the back of the little finger on his left hand, caused by holding it under the haft of the picker, or poker, for keeping up the point. These tools are generally made out of ⅞-inch round iron, with steel tips. The picker is flattened out to form a blade about 1 foot long. The remaining part is left round to form the haft. The whole length rarely exceeds 30 inches, the average being about 26 inches. They are sharpened to a point, or narrow chisel-edge, and tempered in the same way as picks. They are held by the miners in one hand, and struck by a hammer held in the other hand. When they have entered they are often used like short levers for loosening or clearing out the ground.

Fig. 171 shows a "set" or "moil," used for cutting ground where it requires to be done evenly, such as in the case of cutting "hitches," or preparing seatings for pit work, or forming a regular bedding for supporting a wedging-curb for tubbing shafts, and for various kindred operations. Sometimes the tip is sharpened to a diamond-point, or to a circular form, to suit particular cases. Most usually it is shaped like the tip of a poker, or picker. When intended for single-hand use, sets do not often exceed 4lbs. weight. If much heavier than this they are called *double*-hand sets, and are the more useful size. They are often made of cast-steel borer-bars, or of a bar of wrought-iron with a tongue of steel welded in to form the cutting part. After sharpening they are hardened and tempered like ordinary borers.

Sets of this character, with chisel tips, are in many cases used for working the native copper accumulations of Lake Superior.

Fig. 172 represents an iron "socket-bar" or "beche," used for drawing cartridges, or broken drills, out of ordinary bore-holes by wedging the socket over them.

Fig. 173 represents a "pointed crowbar." Fig. 174 is a "pinch-bar," with a chisel-edge on one extremity. Sometimes one end of these bars

is left blunt for striking on. Fig. 175 shows another pointed crowbar. Fig. 176 is called a "crook-bar," and is also pointed at one end. When the ends are shaped as at *s*, with Λ points, it forms a "timber-bar," useful for moving heavy timber. In this case the bend of one end is usually opposite to that of the other, and one bend is somewhat shorter than the other. Fig. 177 is a crook-bar, occasionally used for dragging stones and lumps out of loose ground.

Bars are very useful in mining operations for levering out ground, and for splitting rocks traversed by cleavage planes. They are also useful, in some instances, for forcing down coal after undercutting, and are constantly employed for moving or purchasing heavy weights.

Bars are nearly always made of round iron with steel at the extremities, welded on by a splice or split weld. They require occasional sharpening, and are tempered like borers—generally to a blue tinge. For lightness they are now and then made hollow. They usually range in length from 3 to 5 feet. A convenient size is 4 feet or $4\frac{1}{2}$ feet long and $1\frac{1}{8}$ to $1\frac{1}{4}$ inch diameter for ordinary work. They are worth about from 12*s.* to 15*s.* per cwt., and each bar weighs from 12 to 24lbs.

Fig. 178 shows a "claw-bar," well suited for

eye and two blades, one standing like a hoe, and the other at right angles to it, like the blade of an axe. The ordinary-sized head weighs about 5lbs. It is mounted on a helve like a common pick. One smith and striker will make five of these heads per day. The edges are generally sharpened—which is seldom required—by filing them when hot, and they are tempered to about *blue*. Fig. 187A shows a top view of the head.

Fig. 188 represents the head of a "pick-mattock," used for a similar purpose. The pick stem is useful for loosening harder portions of the ground. When the blade edge is turned parallel with the helve it is called a "pickaxe." Axe and pick mattocks from 5 to 8lbs. each can be bought from tool-makers at about 40*s*. per cwt.

Fig. 189 represents a "mortise chisel," often found useful for framing timber work. Miners' mortise chisels are made with iron handles, with steel welded on the back of the blade to form the cutting edge, which is usually from $\frac{5}{8}$ to 1 inch wide, and tempered straw colour. Sometimes they are made with a socket for receiving a wooden handle, as in Fig. 190. This is the sort always sold by ironmongers at from 1*s*. to 1*s*. 6*d*. each. Socket-firmer chisels—Fig. 191—are used for wide mortises. 1 and $1\frac{1}{4}$ inch are useful sizes, and cost from 10*d*. to 1*s*. 3*d*. each.

Fig. 192 represents a miner's "screw-auger," much used for boring pin or bolt holes through timber. The cross handle of wood is fastened by driving it on the flattened dagger at the top of the auger-stem, which is afterwards *clenched*, as shown; or by forming a round eye on the top of the auger-stem, so that the handle can be driven into it. A more durable auger, but less free for cutting, known as the "barrel" or "shell auger," is shown by Fig. 193. Augers of this type, with long shells, are known as "treenail" or "long-pod augers."

A gouge, Fig. 194, is used with these augers for cutting out a circular bit of wood, where a hole is to be commenced, to enable the bit to catch. Augers are drawn out of the holes at intervals when boring, to clear out the chips or dust. The cutting part is of steel, and the stem of iron. They are generally bought ready made. The most convenient sizes for mining purposes are $\frac{5}{8}$, $\frac{3}{4}$, 1, and $1\frac{1}{8}$ inch diameter of bit. They cost from 9*d.* to 1*s.* 6*d.* each, without handles. Eyed augers 2*d.* to 6*d.* extra. The cutting edge is occasionally sharpened with a dead smooth file, or a thin hone stone.

Fig. 195 shows the "skewnose auger," often used by platelayers.

When required for a deep reach, the stem of an

auger may be cut off, and a piece welded in to make it of any required length.

Fig. 195A shows a "pad-handle," used for receiving augers of different types and sizes, either of which fits into a metal socket, where it is secured by a set-pin at the side, as shown.

A strong "spike-gimlet," which is a small kind of barrel-auger with a screw tip, is also a very useful tool. A strongly-made one, ¼-inch size, costs about 9*d.*

Fig. 196 shows a form of "rake" which is used in many collieries and mines for separating lumps from the small stuff, and sometimes for facilitating the picking out of rubbish or impurities from mineral heaps. The rake illustrated has a wooden cross-piece, to which teeth of iron or steel are fastened, and a wooden handle is wedged in the middle. Sometimes the cross-piece is made of iron, through which the teeth are riveted, and provided with a socket to receive the handle. These are best known as "gravel rakes," and cost from 2½*d.* to 3*d.* per tooth. The length of the teeth, and their distance apart, vary according to the character of the work required to be done.

Fig. 197 shows a "brace-key," or "tiller," which consists of two iron handles screwed together in opposite ways, so as to clip between them the rods used in deep borings. When the

handles are screwed on firmly they form two levers for turning the rods as required, the top length of rod being furnished with a swivel. Sometimes the levers are welded to a short intermediate length of boring-rod. Their extremities are occasionally turned up at right angles.

Instead of tillers of this class, some boring-masters prefer to employ a wooden lever or hand-spike, which passes through an eye in the rods just below the swivel-joint. The reason is that with the concussion of the rods iron tillers are more jarring to the hands.

Fig. 198 represents the "wrench" in common use for screwing and unscrewing rods employed in sinking bore-holes.

Figs. 199 and 200 represent the "grips," or "lifting-dogs," which are fastened to the end of a rope or chain, and used for letting down or drawing up boring-rods, by catching them under the collar at the joints of the rods. Other forms of grips are used, and sometimes a simple lashing chain is made to answer the same purpose. Perhaps with screw joints the best plan is to use a "drawing-cap," which is a strong iron loop or eye with a socket having an internal thread, so that it can be screwed on the rods and drawn up by a hook.

Fig. 201 represents the "nipping-fork," or "tiger," often used for temporarily supporting

the train of rods while they are being let into, or drawn out of, a bore-hole. The joints of the rods are too large to pass through the nipping-fork, so that when it is placed over the bore-hole the rods cannot run back if one of the joints is resting upon it. In case of an unexpected breakage the nipping-fork is often valuable in preventing the rods from falling down the bore-hole. It is also used as a wrench.

Fig. 202 is a form of "wad-coil," now and then employed for drawing loose stones out of bore-holes, such stones being clipped within the coils.

Fig. 202A shows a "worm," used like worm-augers, for loosening some tough clays at the bottoms of bore-holes. A similar tool, called a "coil-drag," is in some instances employed for drawing up the bottom part of broken rods from bore-holes or pumps. The coil-drag is welded or screwed on to a length of rods, and lowered down to the broken portion. It is then turned around several times until it entwines itself around the broken portion sufficiently tight to draw it up. The coils are often made of a larger diameter at the lower part than upwards, and frequently the tool is made out of a square bar of iron bent diagonally, in order that the angular edge running inside the spiral may grip the tighter. It is proper to remark that in Figs. 202 and 202A the

way in which the coils are represented to twist is reverse to what it should be. They should twist the same way as the joint-screws, otherwise there would be a tendency to unscrewing in use.

Fig. 203 represents a "claw" used for the same purpose. It is lowered into the bore-hole, or pipes, to get below a joint in the broken rods, and is then turned round, so that the claw may get a holdfast under the collar, or knob.

Tools working on these principles are known amongst many miners as "German keys."

Fig. 204 represents the "bell-screw," or "screw-socket," which is also used for drawing broken rods. It is generally furnished with an internal screw tapering with the socket. When let down over a broken rod the socket is designed to embrace the top of the same, so that after a few turns the thread will often make sufficient bite to draw up the rods. The accompanying torsional strain is objectionable on some occasions.

Sometimes a plain socket is filled with wax, and lowered down to take an impression of the top of the unrecovered broken rods, when the nature of the fracture is not shown with sufficient plainness by the recovered portion. Information thus derived may be useful for designing a special tool for raising the rods which have broken off.

By using similar sockets filled with tough clay,

fragments of broken bits, by embedding themselves within it, have been easily removed.

Fig. 205 represents a "grappel," or "trap," used in connection with exploratory bore-holes, in which the borers used are constructed with narrow bits arranged on a cylinder or ring, so as to make an annular cut, with a solid *core*, *column*, or *carrot* in the centre. The tool illustrated is used for cutting off and raising the carrots. It consists of a cylinder with several *teeth* or *pauls*, hinged around the bottom, and forced towards the centre by springs. After the boring-bit is taken off from the rods, this tool is fastened on instead, and dropped down the bore-hole. The teeth slip over the carrot nearly down to its base. The rods are next slightly moved up and down in quick succession, so that the teeth may nibble notches into the side of the carrot, as shown. A sudden upward jerk is afterwards given to the rods, and the carrot snaps off near the bottom. Being thus detached, and within the cylinder, it can be raised to the surface, as the teeth at the bottom close inwards, and prevent the carrot from dropping out. A heavy iron ring is sometimes employed, instead of the springs, for pressing the teeth inwards. In other cases the springs are fastened to the outside of the cylinder—holes being made through the side so that the teeth may

be pressed inwards—and a wedge on the outside of the cylinder is used for snapping off the carrot. This tool is revolved—turned like an auger—so that the teeth cut away a *neck* all around the bottom of the carrot, where it is intended to be broken.

When carrots are cut in a bore-hole, they afford an excellent opportunity for ascertaining with the greatest certainty the *mineral* and *fossil* characters of the strata which are passed through; and they often reveal lines of stratification, so that the true *power* or thickness of any stratum can be determined by multiplying its carrot length, or vertical measurement, by the *cosine* of the angle of its *dip* from the horizon. This contrivance then is a kind of *witness-trap*, as we have heard it called, which brings to view the soundest and most reliable testimony regarding the strata which have been pierced by the bore-hole.

A similarly-designed tool, called a "bell-box," with pauls, Fig. 206, is occasionally used for passing over the joints or projections on broken rods for drawing them up. It is not unusual to find bell-screws fastened to the ends of forked rods, after the manner of the bell-box here noticed. The hole then passes completely through the socket portion, so that, if needful, the top of the broken rod may pass up between the fork, in

order that the internal screw may get a holdfast around the first joint below the fracture.

Fig. 207 shows a "stud-block," which is used for suspending tube or pipe linings for bore-holes, either for putting them down or drawing them up. It consists of a block made to fit inside the end of the tube, and attached to the rods. In the side of the block are fixed iron studs for slipping into slits cut in the side of the tube, like a *bayonet-joint*, so that it may be suspended as illustrated.

Fig. 208 shows a "spring-dart," used for the same purpose.

Sometimes a conical plug with a screw cut around the outside for tightening itself in the upper end of the tube is used for raising and lowering the linings.

"Heating-tongs" resemble a smith's tongs, but they are made circular to clip around the tube lining of a bore-hole. The part which embraces the tube is made very stout to retain heat for melting solder at joints, for uniting some sorts of tubing, by making the stout part red-hot, and causing it to surround the joint. The "heater," which is a heavy bar of iron, dropped hot down the tube by a chain, is used for the same purpose.

Occasionally it has been found necessary to cut

off the tube linings in bore-holes. This is done by fastening on the end of the rods a taper block pointing downwards. A serrated tooth projects by the force of a stiff spring from the side of the block. When this contrivance is forced down inside the tube, the tooth retires, and when opposite the required point the rods are turned around by a lever, so that the tooth, by pressing tightly against the inside of the tube, cuts a groove all around and severs it.

Fig. 209 represents the "scraper," or "spreader," used for spreading ore when it is being dressed on the frame-table and racks. Sometimes the pattern is like the "solid half-moon hoe," as at *a*. The scraper is like a broad turnip-hoe, fitted with a long handle. It may be simply a piece of wood nailed across one end of a long handle.

Fig. 210 shows the "broom," used for moving ore about when it is undergoing dressing in the *tye* and other apparatus. It is a little smaller than the common broom. The broom is generally made of *heath*. Birch would be too rough.

Fig. 210A represents the "horn," used for washing and cleaning the dressing-frames and tables. In the case of *tin*-dressing, a thin surface of ore left in the frame is washed down into a sort of chest, called a "cover," by water dipped

up in the horn. The handle, about 5 feet long, is fitted and wedged to a bullock's horn, which is cut off at the point and plugged up with wood to form a water-tight bottom.

The "limp," used for scraping mineral off a jigging-sieve, is a piece of board, or sheet-iron, about a foot wide, and formed semicircularly, resembling half the head of a small cask.

The plate of a "bulling-shovel," also used in ore-dressing, is shown by Fig. 211.

Fig. 212 represents a "dipper," or "dip-scuttle," or "bail," used for dipping water out of a shallow place. The scoop part is generally made of elm board. The sides and back are high for holding the water. Sometimes a piece of board is nailed on the top, at the back, to prevent the water from spilling over. The long wooden handle, passing through the scoop, enables it to be used like a shovel.

Fig. 213 represents a platelayer's "keying-hammer," used for driving keys in the chairs of tramroads and railways, for securing the rails. One stump is made half-round for this purpose. In some instances both stumps are the same.

Fig. 214 represents a "beater," or "beating-pick." The cross-piece on one tip is used for packing in ballast under the *sleepers* of tramroads or railways. A similar tool, made stouter, but

without the pointed stem—*i.e.*, with the beating stem only—is known under the name of a "packing-tool."

Fig. 215 represents a "rail-gauge," employed in laying or repairing railroads or tramways, for showing the proper gauge or width between the rails. Fig. 216 is another, with two discs on a round bar, faced in a lathe, and termed a "rolling rail-gauge."

Fig. 217 represents a steel "punch," and Fig. 218 a steel "set," used in some instances for laying rails. Both are furnished with iron handles, made of light rod-iron, bent around the tool. A platelayer's "driver," or "drifting-punch," is a long form of punch resembling Fig. 217, but with a *flat* end suitable for driving out keys, &c.

Fig. 219 illustrates a "rail-cramp," used for bending rails and tramplates for going round curves. A spanner, shown, is used for turning the nut working on the ram, after a rail is adjusted in the claws. About 6*d.* per lb. is the value of cramps of this kind.

Fig. 220 represents a "bottle-jack," which is very useful in mines for raising heavy weights, and, in some instances, for supporting timber undergoing renewal in heavy ground, or for forcing the pieces into their proper positions.

Fig. 221 shows the extensively-used "traversing-jack."

A bottle-jack to lift 6 tons costs about £3. A good traversing-jack to lift the same weight may be bought for about £7.

Very serviceable hydraulic lifting-jacks can now be obtained. One to lift 6 tons, weight not exceeding 70lbs., costs about £10. If traversing, about £3 extra.

Fig. 222 represents a "lewis," which is a contrivance made of iron, and often used in raising or drawing heavy weights, particularly in quarries. The two side-pieces, which are made with taper, are dropped into a dovetail recess, formed in the piece to be removed. The ring-tongue is then put in between, and a bolt is afterwards passed through all three of the pieces, and secured by a small split-key inserted through its point. If the lifting-gear is next attached to the ring for raising the piece, the lewis will obtain a firm hold by wedging itself tightly in the dovetail.

Fig. 223 represents a "nipper," of frequent use in quarries for raising blocks of stone. The fangs open and close on a hinge, like a scissors joint, so that the points may span over a block of stone, and catch in two small notches cut in opposite sides. When the hoisting-gear is

applied to the ring, the bridle-chains make the nipper clip firmly in the notches, and the heavier the weight the more tightly it holds. A very similar contrivance is used for raising timber.

Fig. 224 represents a "cant-hook," found convenient for rolling over timber by means of a lever or handspike passed through the ring. Sometimes two of them are strung on a chain, and used instead of a nipper. These, made somewhat stronger in the hook, are known as "quarry-dogs" or "crane-hooks."

The last tool we shall notice is the "marline-spike," Fig. 225, used for rope splicing. It consists of a round pointed piece of steel, called the "tusk," fixed in a stout wooden handle. A tusk about 6 inches long, by $\frac{3}{4}$ inch diameter in the largest place, is a very convenient size; but much larger ones are used for splicing very stout ropes, such as capstan ropes. Sometimes the marline-spike is made entirely of steel, or iron steeled in the point, with a hole in the head for passing through a string, or with a pear-shaped loop to form the handle. In other cases the head of the spike is turned off at right angles to form a handle.

Besides understanding how to tie good hitches and knots, every miner should be able to splice well. A *short* splice is a very useful one; but when the rope has to run through tackle or blocks a *long* splice is necessary.

HELVES OR HANDLES.

Many of the tools which we have noticed are furnished with wooden *helves*, *handles*, *shafts*, or *sticks*, as they are variously termed. A tool helve ought to combine three qualities, viz.:—toughness, with moderate hardness; slight elasticity; and lightness. It should also be sufficiently large to enable it to be held firmly in the hand without cramping the muscles. Ash-wood complies with these conditions better than any other material which is easily procured in this country.

Hickory—a valuable American nut-bearing tree, of various kinds, similar to the walnut tribe —is largely used for helving tools of American manufacture, many of which find their way into English markets.* This wood makes very good helves, and is commonly considered to be particularly suited for axes. Some of it is peculiar for the

* Hickory is very much employed in the manufacture of handspikes—imported from North America, ready made, and weighing about 20lbs. each—fishing-rods, shafts, &c.

lozenge-shape structure of its tissue. For most purposes, however, good ash helves are unsurpassed.*

The holding surface of a helve has all its angles rounded off smoothly, so that it may be used without galling the hands. The best shape is either *oval* or *round*, in cross section. *Oval* is the better shape for picks, sledges, and axes, because it gives the hand greater control over the directing of the tool; but in the case of shovels *round* is generally preferred for sliding and turning in the hand. When shovel helves of short or medium length are used, the crutch, or open handle, is serviceable, not only for affording a large pressing surface to one hand, but also for controlling the turning of the helve in the other, and for preventing any capsizing of the plate when filled; but when long helves are used—as with the Devon shovel—their high inclination enables the helves themselves to afford a large pressing surface, and the weight upon the plate is so much below the level of the hands that it has hardly any tendency to capsize; hence the ordinary grasp of the hand gives sufficient control over the turning of the helve when needed. Very common oval

* The following is the order of arrangement usually accepted as showing the relative values of a few sorts of wood for *elasticity* :—ash, hazel, hickory, lancewood, yew.

sizes are—for small tools, $1\frac{1}{2}$ inch × $\frac{3}{4}$ inch; for medium size, $1\frac{5}{8}$ × $1\frac{1}{8}$; and for large size, $1\frac{3}{4}$ × $1\frac{1}{4}$ or $1\frac{3}{8}$. The length is not usually less than 18 inches, or more than 36 inches; 24 to 30 inches being most common.

Round helves may be said to vary from $1\frac{1}{8}$ to $1\frac{3}{4}$ inch average diameter; $1\frac{3}{8}$ inch being a very convenient size.

Long shovel helves are commonly from 4 to 5 feet long, and short ones about 30 inches long, except where required for use in confined places.

Short-helved shovels are usually bought with helves fitted to them.

Spare shovel helves are often kept in mine stores, although it is comparatively seldom that one has to be replaced; but the helves of sledges, and of picks especially, are found to break so often that a large stock is usually kept at the mine for replacing broken ones.* Fig. 226 represents a pick helve, and a sledge helve is shown by Fig. 227.

Both sorts are generally split out of round logs of timber into shapes represented by Figs. 228 and 229. They are next *rough hewn* by an axe into the shapes represented by Figs. 230 and 231.

* Axe handles do not often break. They are usually replaced by a handle made out of a pick-helve, when they require to be renewed at mines.

Afterwards they are *dressed* by drawing-knives, spokeshaves, or planes, until they assume the forms shown by Figs. 226 and 227. In consequence of the feathered part, *a*, *b*, occurring in a pick helve, there is some extent of timber wasted in forming the haft, *b*, *c*, as will be seen by reference to Fig. 226, where the dotted lines show the outline of the piece of timber from which the helve is made. It will be seen this does not apply to sledge helves, Fig. 227, unless they are formed with a feather, as in Figs. 24 and 28, which is not usual. The sizes of helves are, to a certain degree, regulated by the sizes of the eyes, into which they must fit tightly. This is always the case with the feather of a pick helve, which ought to taper as represented in Fig. 226, so that the helve might be taken from a worn-out or broken tool, and used in another, or refitted in cases of *wincing*. As a rule, it is about 1 to 1¼ inch thick, by 3 to 4 inches wide, in the largest part of the feather.

A helve should be fitted into the eye of any tool as nicely as possible, by driving it partly in and withdrawing it a few times, so that the too prominent parts, which will be marked by having pressed against the inside of the eye, may be reduced until an equal bearing is obtained. Before the helve is permanently wedged in, it is neces-

sary to see that the stems stand perpendicular, or at a proper angle, thereto. Almost invariably double-stemmed picks should be fixed square with their helves. To test that they are so before wedging up, it is common, after driving a pick-head on the feather end, to place the other end of the helve against a fixed point on the ground—usually, for the time being, against the shoe worn on left foot. With one stem then pointing downwards, a line is scratched on the ground with its tip. The other tip is next turned down, and if it do not touch the same line, the head will be out of square, and must be struck, so that the lines scratched by both tips coincide. The helve is then fastened by a hard oak wedge (about $\frac{3}{8}$ inch thick, and as wide as the eye is long), which is driven at the top of the feather, in the direction of its long axis, as shaded in Fig. 48. An entrance is made for the oak wedge by a broad steel chisel. Sometimes narrow iron wedges are driven in across the oak one.

In some instances the eye is "threaded" over the haft, and then the feather tapers the opposite way, as in Fig. 187.

For making helves, suitable ash timber in the round is cut by a crosscut saw into logs of lengths corresponding with the lengths of the helves required. The logs are then split or

cleaved, as required, by an iron wedge, like Fig. 160, driven in at one end.

The manner in which helves are cleft is of some importance. It is well known that in every tree the wood is more porous at the circumference than at the centre, and consequently the outer part shrinks more by drying than the inner part.* It is very objectionable to have helves warp *sideways*, and to avoid this, as well as to counteract, as far as possible, the tendency of helves to warp at all, they require to be cleft in a particular direction, so that the long axis of the oval or feather shall *radiate* from the centre of the log, similarly to the medullary rays, or just like the cracks often seen in the end of a felled tree after drying.

The foregoing will be easily understood by reference to Fig. 232, which represents the end of a log, with lines showing how it is cleft radially in segments for forming pick helves as described. The dotted lines show the feathered part afterwards formed out of each piece. At *a*, the outside angles are chopped off, to suit for a straight axe

* Boards often warp from this cause, and the same reason explains why the *middle cut* in a piece of timber over the saw-pit so commonly requires no wedging for clearing the saw, because the tendency of the outer portion of the timber to contract naturally causes the separated pieces to splay away from each other.

handle. The diameter of the log must slightly exceed twice the widest part of the feather. In converting larger logs there is ample latitude for the exercise of good judgment in making the most of timber. In Fig. 233 the log is first *halved*, then *quartered*, and each quarter is cleft in the most advantageous manner into pick or sledge helves, or both, according to the sorts and sizes required.

The best helves are those from nearest the centre. In Fig. 234, and part of Fig. 235, the quartering is *unequal* to economise the timber. A cleaver will often apply unequal quartering for gaining a few more helves out of a log than could be otherwise obtained; and when some of various sizes are required, and there is much difference in the sizes of the logs, a considerable amount of contriving is necessary to make the timber go as far as possible. Generally a few wasters may be expected, much according to the skill of the cleaver, but with good straight-grained timber there need hardly be any. A log of suitable ash, 1 foot girt (about 15$\frac{1}{2}$ inches diameter), is expected to cleave into 36 or 38 good coal pick helves, each of about 3 inches wide, by 1$\frac{1}{8}$ inch thick, in the largest part of the feather.

The same timber would cleave into about twice as many sledge helves.

As regards the number of helves which one man will cleave per day, there is great variableness, as in all other things, according to the skill of the handicraftsman.

Two men are required to use a crosscut saw, and it is considered a fair day's work for both of them, with good timber, to cross cut sufficient ash into suitable lengths, and cleave and rough hew about 12 dozen 30-inch pick helves per day, or about double as many sledge helves.

It is considered that one man will afterwards *dress* about 5 dozen rough-hewn *pick* helves per day, or 10 dozen *sledge* helves; and that he will *fit* and *wedge up* about 7 dozen *dressed* helves into picks, or 10 dozen into sledges, per day.

In some places a carpenter is considered to *cleave, rough hew, dress, fit, and wedge up* 2 dozen pick helves per day, or 4 dozen sledge helves in the same time.

At many collieries and mines, dressed pick helves are sold to the men at 4*d.* each, and sometimes the colliers do the *fitting* and *wedging up* themselves. In other cases a new helve, fitted and wedged complete, is sold for 5*d.* to 6*d.* each for *picks*, and 4*d.* each for *sledges.*

Helves ought always to be cleaved and rough hewn when the timber is green, and then they should be stored away for about three months to

season and dry before use, after which time any slight warp can be corrected in dressing.

At some collieries, where the grain of the ash used is not straight, or good for splitting, the logs are divided by a circular saw. This often produces very bad helves, when, as often, the grain does not run properly *with* the haft; consequently, they warp and break too easily. For the same reason they are not so easily hewn and dressed as cleft helves.

The price generally paid for simply *hewing* and *dressing* pick helves which have been sawn out of curly-grained ash is 2*s.* 6*d.* per dozen.

The expense of a new helve is not of so much importance as the delay often occasioned by the breaking of one. It is always more profitable in the end to give a little more for good helves than to go on using poor ones because they are procurable at a less cost. At one colliery where sawn helves are used, we ascertained that two dozen pick helves, per hundred hewers, were broken per week, although the picks were not exposed to very hard holing or cutting, and only one face of hard dead work was being carried on at the time. This gives about four weeks as the average duration of each helve; whereas a good helve ought to last more than four times as long under the same conditions.

It is by no means an uncommon thing in col-

lieries to find the same helve, where good ones are used, last a hewer in regular work upwards of twelve or eighteen months. In collieries where very hard coal seams are worked in South Wales, and where a hard *bottom* has to be cut very much, moderately good cleft helves are found to endure six or seven weeks on an average—bottom picks included. As a rule, pick helves are exposed to much greater strain in metalliferous mines, and their duration is considerably shortened, in some instances not exceeding a fortnight.

A little observation bestowed upon this subject will sometimes show a surprising disparity between different sorts of ash, as regards durableness for helves, although in external appearance there is nothing very dissimilar.

In some colliery districts, good cleft helves in the rough-hewn state, and 30 to 34 inches long, are sold at from 2*s.* 3*d.* to 2*s.* 6*d.* per dozen for *holing* and *cutting* picks, and 2*s.* 9*d.* to 3*s.* per dozen for *bottom* picks.

The haft of an axe handle is generally oval in section. Ordinary axe handles range from 18 to 26 inches long, with a difference of 2 inches between each intermediate size. If *straight,* they cost, dressed, from 4*d.* to 6*d.* each, and if *bent,* from 1*d.* to 2*d.* extra.

Felling axe handles, straight, and from 34 to

36 inches long, cost from 6*d.* to 7*d.* each in ironmongers' shops.

Wedge axe handles, from 32 to 34 inches long, are sold at about 10*d.* to 1*s.* each.

A round-sectioned helve, as before observed, is the most convenient shape for a shovel. The grain should run *with* the handle. The best handles are *bent,* after steaming, out of tough, straight-grained ash. If *sawn* out, and they are cross-grained between the straps, helves do not afford sufficient support to the shovel.

Gravel shovel helves, about 30 inches long, with crutch handles, are commonly sold for about 6*d.* each, best quality. Long shovel helves cost about the same price, and up to 9*d.* each.

The common growth of ash is confined to temperate and northern latitudes. Locality, climate, and soil each greatly influence the quality of the timber, and sometimes a very remarkable distinction exists in the natures of different varieties of ash-trees grown in proximate positions.

Ash produced on land which is rather poor, or only moderately rich, is said to be most suitable for helves.

Ash does not suffer by altitude, if it is moderately well sheltered. When it grows in very moist or boggy soil, the timber is not very solid or tough.

If growing at the bottom of a slope, near a stream, in a loamy soil, where it is not *wet*, but kept slightly moist during the heat of summer, ash thrives in an excellent manner.*

It often grows to perfection on the sheltered sides of hills and glens.

A uniform hazelly loam is very congenial soil for ash. It produces tough, straight-grained, and durable timber, of the character required for helves.

Some very tough and hearty ash, good for riving into helves, is found to grow in coldish parts of our country, on clayey soils covering argillaceous rocks, about hill-sides often exposed to the westerly wind, but sheltered from the east.†

Ash may be said to be of rapid growth, but the difference of soil influences the growth so much that trees fifty years old may each give seventy-five feet of timber in one coppice, while in another they may not yield thirty feet each.

It is not well for ash intended for helves to grow

* Ash roots are very strong suckers of the nutritive properties of soil, and they will reach as far as 40 or 50 yards from a tree of eighty years' growth. The roots often impoverish pasture and crops growing over them to a very marked extent, which is shown in stunted vegetation, so that it is unadvisable to adopt ash for hedgerow planting and such-like.

† The timber which has grown on the west side of a tree is noticed by some woodmen to be harder than other parts, and many sawyers aver that they can readily detect the difference in sawing the timber.

very rapidly. A moderate rate of growth gives the greatest toughness and compactness of fibre.

Foresters consider that the most profitable age for felling ash is from ninety to one hundred years' growth. It is then generally "ripe," which is indicated by the "leading point" beginning to fail and to lose its verdure. But for making helves, this is too old to cleave well. The best age for felling ash for helves is from forty to fifty years. It will then cleave in a proper manner, and be hearty and tough. At this age it is termed about "half ripe." The proper season for felling it is between October and February, when the sap is down.

Some ash is imported from Canada. About forty cubic feet are allowed to the ton, and the same quantity if not "squared" makes a "load."*

The price of good ash for helves generally ranges in this country from 9*d.* to 1*s.* 4*d.* per cubic foot—standing in the coppice—including the measurement of branches over 6 inches girth but all the rest, with brushwood, &c., is included free.

Not unfrequently the difficulties of getting the timber away from the place where it grows influence the value in parts of England to the

* A variety of timber called "hally wood," not much unlike ash, is occasionally imported from New York.

extent of 3*d*. per foot. In country places, large standing lots can often be bought for 6*d*. per cubic foot, the branches over 6 inches girth being measured in, but tops, brushwood, &c., go free.

At seaport towns it costs about 1*s*. 4*d*. per foot in the rough.

Sometimes owners sell trees felled and lopped for 1*s*. to 1*s*. 3*d*. per cubic foot in the wood; and they consider the value of the *tops*, *brushwood*, &c., sufficient to pay for the labour of cultivating the young trees and felling.

Forty to fifty years' growth may be considered to produce, under average circumstances in this country, about forty cubic feet of measurable timber in each tree, and ninety trees will grow, on an average, per acre.

NOTES AND SUPPLEMENTARY MATTER.

NOTE TO PAGE 4.

Amount of loss during conversion of pig-iron to wrought-iron.—27 to 28 cwts. of forge pig-iron make a ton of cheap merchant iron, or common railway bars cut to length. 30 to 35 cwts. of good grey pig-iron are used for the production of a ton of good merchant bars, sheets, or rods for wire-drawing.

NOTE TO PAGE 4.

For proportioning the sizes of materials for bearing certain strains—as in the case of boring rods, &c.—and for estimating the weights of tools or implements, the following data are now and then serviceable :—

METALS.	Specific grav.	Weight of a cubic foot, in lbs.	BREAKING STRAIN IN LBS. PER SQUARE INCH. Tension. Res. to tearing.	Compression. Res. to crushing.
Brass—cast	8·4	524	18,000	10,300
„ wire	8·5	530	49,000	
Copper—cast	8·7	543	19,000	11,700
„ wire	9·0	562	60,000	
Iron—cast	7·0 to 7·26	437 to 453	17,000 to 28,000	80,000 to 100,000
„ wrought, bar	7·69	480	55,000 to 70,000	35,000 to 40,000
„ plates			50,000	
„ „ double riveted seams			35,000	
„ „ single „ seams			28,000	
„ wire			85,000	
„ wire ropes			85,000	
Lead—cast	11·4	712	1,824	7,000

Metals.	Specific gravity.	Weight of a cubic foot, in lbs.	Breaking Strain in lbs. per square inch. Tension. Res. to tearing.	Compression. Res. to crushing.
Steel—tempered	7·85	490	100,000 to 120,000	
„ hardened	7·78	485	74,000 to 80,000	
Tin	7·30	456	4,750	15,000
Zinc	7·00	437	7,500	
Dry Timber.				
Ash	·8	50	17,000	9,100
Beech	·7	44	11,000	9,100
Birch	·7	44	15,000	6,000
Chestnut	·53	33	12,000	
Elm	·56	35	12,500	10,000
Hazel			17,000	
Larch	·56	35	9,600	5,400
Oak—English	·93	58	18,000	10,500
„ American			11,000	
Spruce and Red Deal . .	·65	40	12,000	5,700

Weight of Round and Square Bar-iron in lbs. per lineal foot.

Size. Inches.	Round bars. lbs.	Square bars. lbs.	Size. Inches.	Round bars. lbs.	Square bars. lbs.
$\frac{1}{4}$	·164	·209	2	10·49	13·36
$\frac{3}{8}$	·369	·470	$2\frac{1}{8}$	11·84	15·08
$\frac{1}{2}$	·655	·835	$2\frac{1}{4}$	13·27	16·91
$\frac{5}{8}$	1·024	1·304	$2\frac{3}{8}$	14·79	18·84
$\frac{3}{4}$	1·475	1·879	$2\frac{1}{2}$	16·39	20·87
$\frac{7}{8}$	2·008	2·556	$2\frac{5}{8}$	18·07	23·11
1	2·622	3·340	$2\frac{3}{4}$	19·84	25·26
$1\frac{1}{8}$	3·317	4·227	$2\frac{7}{8}$	21·68	27·61
$1\frac{1}{4}$	4·097	5·219	3	23·60	30·07
$1\frac{3}{8}$	4·960	6·315	$3\frac{1}{4}$	27·70	35·28
$1\frac{1}{2}$	5·900	7·517	$3\frac{1}{2}$	32·13	40·91
$1\frac{5}{8}$	6·925	8·820	$3\frac{3}{4}$	36·89	46·97
$1\frac{3}{4}$	8·032	10·227	4	41·97	53·44
$1\frac{7}{8}$	9·222	11·742	$4\frac{1}{4}$	47·38	60·32

WEIGHT OF METAL SHEETS IN LBS. PER SUPERFICIAL FOOT.

Thickness.		Iron.	Copper.	Lead.	Thickness.		Iron.	Copper.	Lead.
Inch.	B.W.G.				Inch.	B.W.G.			
$\frac{1}{64}$	28	·63	·72	·92	$\frac{1}{2}$		20·00	22·90	29·55
$\frac{1}{32}$	22	1·25	1·43	1·84	$\frac{9}{16}$		22·50	25·76	33·24
$\frac{1}{16}$	16	2·50	2·86	3·69	$\frac{5}{8}$		25·00	28·63	36·93
$\frac{3}{32}$	13	3·75	4·29	5·53	$\frac{11}{16}$		27·50	31·49	40·62
$\frac{1}{8}$	11	5·00	5·73	7·38	$\frac{3}{4}$		30·00	34·35	44·32
$\frac{3}{16}$	7	7·50	8·59	11·07	$\frac{13}{16}$		32·50	37·21	48·01
$\frac{1}{4}$	4	10·00	11·45	14·77	$\frac{7}{8}$		35·00	40·08	51·70
$\frac{5}{16}$	1	12·50	14·31	18·46	$\frac{15}{16}$		37·50	42·94	55·39
$\frac{3}{8}$		15·00	17·18	22·15	1		40·00	45·80	59·10
$\frac{7}{16}$		17·50	20·04	25·84					

Taking wrought-iron as an example, although a bar of given quality will not break until each square inch of its sectional area has to bear a tensional strain of, say, 55,000lbs., or a compressive strain of, say, 35,000lbs., yet it is not safe in actual practice to load the iron up to more than from $\frac{1}{8}$th to $\frac{1}{3}$rd of that strain. The safe "working load" is found by dividing the "breaking strain" by a certain figure, termed a "factor of safety." When the strain brought to bear upon any material is perfectly steady and uniform, it is called a "dead load;" but when, as in the case of the moving parts of a machine, the strain is irregular, vibratory, or sudden, it is called a "live load." Factors of safety vary accordingly, and may be registered as follows:—

For dead loads 3, for live loads 5 to 6, in the case of *Metals.*

For dead loads 5, for live loads 8 to 10, in the case of *Timber* and *Masonry.*

When, however, dealing with cases like pump rods, which may be submitted to extra strains by the jamming of pump buckets or otherwise, and which are liable to quiver or shake considerably in work, the factors of safety are increased to 3 or even 4 times greater than those given above, or, to meet the same end, the strain on the pump rods is taken at 3 or 4 times

greater than the nominal "load," and the ordinary factors of safety are then adopted.

It is useful to carry in mind that a square foot of wrought-iron plate, 1-inch thick, weighs 40lbs., because, by reckoning parts thereof, the weights of plates of other thicknesses, as well as the weights of different sizes of square and flat bars, may be easily worked out mentally.

To find the equivalent weights of other metals, multiply the weight of wrought-iron by 1·021 for steel, by ·928 for cast-iron, by 1·092 for cast brass, by 1·105 for brass wire, by 1·131 for cast copper, by 1·171 for copper wire, by 1·15 for sheet copper, by 1·483 for lead, by ·950 for tin, or by ·910 for zinc, as the case may be.

Weight and Strength of Chains.

Short-link Chains.

Diameter in inches of iron in links.	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$
Weight in lbs. per fathom.	$5\frac{1}{2}$	8	11	14	18	23	28	32	88	44	50	56	71	87
Proof strain in cwts.	$25\frac{1}{2}$	$36\frac{3}{4}$	$51\frac{1}{4}$	$65\frac{1}{3}$	85	102	127	147	177	200	236	268	334	408

To find the weight which ordinary short-link chains will carry with safety.—Multiply the square of the diameter (reckoned in 16ths of an inch) by ·035; the product will be the weight in tons. Thus, in the case of a $\frac{3}{4}$-inch chain: $\frac{3}{4} = \frac{12}{16}$, and $12 \times 12 = 144$; then $144 \times {\cdot}035 = 5{\cdot}04$, say 5 tons—the safe working strain. If the squares are divided by 28, a similar answer is obtained. Thus, $144 \div 28 = 5{\cdot}14$ tons. For general purposes 30 may be used as a divisor. The same squares, multiplied by ·052, give approximately the proof strains in tons.

Chain Cables—Stud-link.

Diameter in inches of iron in links.	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2
Weight in lbs. per fathom.	$13\frac{1}{4}$	22	31	43	55	68	84	102	120	148	180
Proof strain in cwts.	80	120	200	270	360	450	560	680	810	1,100	1,440

WEIGHT AND STRENGTH OF WIRE AND HEMP ROPES.

ROUND ROPES.

STEEL WIRE.		IRON WIRE.		HEMP.		EQUIVALENT STRENGTHS.	
Circumference in inches.	Weight per fathom in lbs.	Circumference in inches.	Weight per fathom in lbs.	Circumference in inches.	Weight per fathom in lbs.	Working load in cwts.	Breaking strain in tons.
		¾	½	1½	¾	1½	¾
		⅞	¾	1¾	1	3	1
		1	⅞			4	1¼
¾	½	1⅛	1	2	1½	6	1¾
⅞	¾	1¼	1¼	2¼	2	7	2
1⅛	1	1⅜	1½	2½	2½	8	2½
1¼	1¼	1½	1¾	2¾	3	10	3
		1⅝	2			12	4
1⅜	1½	1¾	2½	3	3½	15	5
1½	1¾	1⅞	3	3½	4	18	6
1⅝	2	2	3¼	3¾	4½	20	6½
		2⅛	3¾	4	5	22	7¼
1¾	2½	2¼	4	4⅓	6	24	8
		2⅜	4½	4¾	6½	27	9
1⅞	3	2½	4¾	5	7	30	10
2	3¼	2⅝	5½	5½	8	33	11
2⅛	3¾	2¾	6	6	9	36	12
2¼	4	2⅞	7	6½	10	42	14
2⅜	4½	3	7½	7	12	45	15
2½	4¾	3⅛	8¼	7½	14	49	16
		3¼	8½			52	17
2⅝	5½	3⅜	9½	8	16	56	18
2¾	6	3½	11	8½	20	66	20
2⅞	7	3⅝	11¾	9	22	70	22
3	7½	3¾	13	9½	25	78	24
		3⅞	13½			80	25
3⅛	8¼	4	14	10	28	85	27
3⅜	9½	4¼	16	11	30	96	29
		4⅜	17			105	32
		4½	18			114	35
3½	11	4⅝	20	12	32	130	40

FLAT ROPES.

Steel Wire.		Iron Wire.		Hemp.		Equivalent Strengths.	
Size in inches.	Weight per fathom in lbs.	Size in inches.	Weight per fathom in lbs.	Size in inches.	Weight per fathom in lbs.	Working load in cwts.	Breaking strain in tons.
		$1\frac{7}{8} \times \frac{1}{2}$	8	3×1	16	32	14
		$2 \times \frac{5}{8}$	11	$4 \times 1\frac{1}{8}$	20	40	18
		$2\frac{3}{4} \times \frac{1}{2}$	12	$5 \times 1\frac{1}{4}$	22	48	20
$1\frac{7}{8} \times \frac{1}{2}$	8	$2\frac{7}{8} \times \frac{9}{16}$	14	$5\frac{1}{4} \times 1\frac{1}{4}$	24	56	22
$2 \times \frac{5}{8}$	10	$3 \times \frac{5}{8}$	16	$5\frac{1}{2} \times 1\frac{3}{8}$	26	64	24
$2\frac{1}{2} \times \frac{1}{2}$	11	$3\frac{1}{4} \times \frac{5}{8}$	18	$5\frac{3}{4} \times 1\frac{1}{2}$	29	72	26
$2\frac{3}{4} \times \frac{1}{2}$	12	$3\frac{1}{2} \times \frac{11}{16}$	21	$6\frac{1}{2} \times 1\frac{1}{2}$	32	80	29
$2\frac{7}{8} \times \frac{9}{16}$	14	$3\frac{3}{4} \times \frac{3}{4}$	24	$6\frac{1}{2} \times 1\frac{5}{8}$	36	88	33
$3 \times \frac{5}{8}$	16	$4 \times \frac{3}{4}$	26	$7 \times 1\frac{7}{8}$	40	96	37
$3\frac{1}{4} \times \frac{5}{8}$	18	$4\frac{1}{4} \times \frac{13}{16}$	28	$7\frac{1}{2} \times 2\frac{1}{8}$	45	110	42
$3\frac{1}{2} \times \frac{11}{16}$	21	$4\frac{1}{2} \times \frac{7}{8}$	32	$8\frac{1}{2} \times 2\frac{1}{4}$	52	120	48
$3\frac{3}{4} \times \frac{3}{4}$	24	$5 \times \frac{7}{8}$	39	$10 \times 2\frac{1}{2}$	64	145	58
$4\frac{1}{4} \times \frac{13}{16}$	28	$5\frac{1}{2} \times 1$	48	$11\frac{1}{2} \times 2\frac{3}{4}$	78	175	70
$4\frac{5}{8} \times \frac{7}{8}$	34	6×1	59	13×3	98	212	86

Ropes differ somewhat in weight and strength according to make.

Note to Page 6.

Oxidation or scaling in a smith's fire.—At the hottest position in a smith's fire there is a surplus of air which will scale iron placed there to be heated. Further away from the blast, all the oxygen is appropriated by the fuel to form carbonic oxide gas, which possesses both reducing and carburizing properties. It will reduce iron scale to metallic iron by combining with the oxygen of the scale, and in its presence iron absorbs part of its carbon to form steel. This gas burns in blue flames on the outside of the fire, and then forms carbonic acid gas. Carbonic acid is an oxidizing agent, which, in the absence of carbonic oxide, readily scales highly-heated iron. It will also oxidize or "burn" the carbon in iron (as well as that and some other constituents of fuel) when at the requisite temperature. In like manner it will reduce heated steel to the state of wrought-iron by

combining with and removing carbon from the steel. By this reaction, carbonic acid is reduced to the state of carbonic oxide, the former consisting, by weight, of 1 of carbon to $2\frac{2}{3}$ of oxygen, the latter of 1 of carbon to $1\frac{1}{3}$ of oxygen.

Notes to Page 12.

Welding test for wrought-iron.—Wrought-iron containing enough of phosphorus to render it to some extent cold-short, can be welded with the *utmost* facility.

A simple test for distinguishing steel and wrought-iron is that of placing a drop of aqua-fortis (nitric acid) upon a brightened surface of each. The acid must be sufficiently dilute to prevent the formation of frothy gas bubbles. The drop placed upon steel becomes darkened to a resemblance of ink through the separation of solid carbon, which remains floating in the acid by reason of not being dissolved like the iron. Acting upon wrought-iron, the drop of acid soon becomes tinged yellowish brown, which gradually changes to a greenish colour. Upon washing off the acid with cold water, very slight rubbing removes almost all trace of the spot from the *iron*, whereas there is a dark stain left upon the *steel*. Steel in a hardened state exhibits more decided and rapid separation of carbon, and bears a deeper stain after washing than the same steel in a softened state. This arises, probably, from the more porous condition of hardened steel, due to its permanent expansion by hardening.

The bevel edge of a hatchet, ground through both wrought-iron and steel, is convenient for this experiment. The line of junction of the iron and steel can usually be seen by reflected light, but if not thus discernible, it can be readily distinguished by drawing a little aqua-fortis across the bevel.

The same dilute acid will act upon brightened grey, chilled grey, mottled, and white cast-iron with much the same effect as produced upon wrought-iron, but with less coloration in the cases of chilled and naturally white cast-irons. In each case, if washed and slightly rubbed, after having been acted upon five or ten minutes by the acid, scarcely any trace of the spot remains upon cast-iron.

Brightened steel, rich in carbon, can be distinguished, when hardened, from mild or slightly carburized steel, similarly

brightened and hardened, by merely placing the two sorts side by side, whereupon the former will be observed to have a decided yellowish tint, but a silvery whiteness will be shown by the latter.

Note to Page 16.

Heat developed in the Bessemer converter during blowing.—The chilling effect of blast blown *downwards* into molten iron is well known. In refining-fires this is compensated by the combustion of a considerable quantity of fuel upon the surface of the molten iron. By introducing the blast at the bottom of a "converter," the heat of chemical combination becomes well diffused throughout, and is largely absorbed by, the charge. In the case of the refinery, the reactions occurring on or near the surface permit the upward escape of heat without directly contributing to the liquefaction of the mass.

Note to Page 17.

Bessemer Steel.—In Sweden, first-class razors and cutlery are made out of steel manufactured by this process from pig-iron derived from very pure iron ores smelted with charcoal. Bessemer steel, or steely-iron, for wire drawing and sheet rolling, contains from 0·05 to 0·15 per cent. of carbon; steel for boat, bridge, and boiler plates, railway axles, and gun barrels from 0·3 to 0·4 per cent. of carbon; for tyres and rails from 0·4 to 0·5 per cent.; for files, razors, and cutlery, 1·0 to 1·5 per cent. Swedish Bessemer steel must be quite suitable for borers and other mining tools.

Note to Page 21.

Case-hardening.—Strongly-heated wrought-iron plunged into fine charcoal powder, or sprinkled with it, becomes skin carburized. Only a very thin coating of steel is formed by the experiment; but, after hardening, it will resist a file. Russian sheet-iron, so generally celebrated for toughness, is hammered —prior to the finishing process—in piles at a red heat, in which the sheets are separated from each other by a thin layer of nearly impalpable charcoal powder. This operation, no doubt, effects a degree of carburization sufficient to partly account for

the excellence of the sheets, which might be called steel, or steely-iron sheets. We have drawn attention, on page 32, to the likelihood of similar skin carburization in the process of oil hardening.

NOTE TO PAGE 24.

Welding Steel.—Some smiths mix a little sal-ammoniac with the borax used for forming a glaze to prevent scaling in drawing heats. About 1 part of the former to 8 or 10 parts of the latter are mixed in a powdered state, and heated over a fire. When melted to a clear liquid, it is poured out to cool, and then pounded up for use as required.

NOTE TO PAGE 27.

Vaporization of Water during process of hardening steel.—Sainte-Claire Deville recently found that the higher the temperature iron is raised to before plunging into water, the less water is decomposed during the first given measure of time after the instant of immersion. He concluded that the affinity of the iron for the oxygen in water decreased with increase of temperature, or, what amounts to the same, that the affinity of hydrogen for its accompanying oxygen in water increased notably with increase of temperature. The fact observed may be influenced by the well-known spheroidal condition which water assumes when in contact with heated metals, besides by the greatly increased tension of the envelope of vapour surrounding a more highly heated mass of iron when in water—a circumstance which would prevent the access of equal quantities of water to the iron.

The phenomenon above referred to must have an influence on the operation of hardening steel. This operation is also greatly influenced by the shape and mass of articles under treatment. A 1-inch cube of steel exposes 6 square inches of surface upon which water can operate for cooling; while a 12-inch cube, containing 1,728 cubic inches, exposes only 864 square inches of surface, or only ½ a square inch of surface per cubic inch of content, instead of 6 square inches per cubic inch, as in the first case. In this example the ratio of cooling surface per cubic inch of content in the two cubes is as 12 to 1, so that to obtain equal effects in the same time, twelve times the

very difficult to "strike" hardness through saw blades which are as much as $\frac{3}{8}$-inch in thickness.

Some reference has been made to the various sorts of tamping in common use in connection with rock blasting. When nitro-glycerine—discovered by Nobel—was first being introduced as an explosive agent, one point, urged strongly in its favour, rested on the convenience it offered regarding tamping. A little soft clay, mould, dust, or sand, gently placed against the charge, afforded sufficient resistance to cause most effective blasts by using nitro-glycerine, because of the instantaneous and violent action of its explosive force. Even water tamping was adequate, and for downward holes nothing could be more convenient. Necessity for claying wet holes disappeared. The charge had simply to be poured in, that it might sink to the bottom of the water. In case a faulty fuse caused a misfire, there was no occasion for risking the loosening out of tamping by prickers, or otherwise, in order to recharge. Tamping bars were, so far, valueless. To be able to discard their use entirely could grieve no one.

The necessity, however, for creating parliamentary restriction against the employment of nitro-glycerine was soon suggested by several calamitous accidents which attended its storage, transit, and use, and which soon caused its destructive peculiarities to be regarded with widespread alarm. Many who looked forward to increased prosperity of mining industry regretted that an explosive agent, possessing after all so much to recommend it, should, notwithstanding, be characterized by such dangerous attributes.

Since that time Nobel set himself the task of discovering a safeguard against the danger, and of producing a compound having practically the enormous strength of nitro-glycerine, yet without its special drawbacks, and his labours have been encouragingly rewarded by the production of *dynamite*, said to consist of about 75 per cent. of nitro-glycerine and 25 per cent. of soft and porous silicious matter.* The compound is of pasty consistence. Lit by fire in the open air it burns away in a

* Porosity seems to be an important character, to render the material sufficiently absorbent to imbibe all the nitro-glycerine, and secure against any separation of the same in free drops, which would be extremely dangerous.

very quiet manner, but if fired by a detonating or percussion cap, or gunpowder, it explodes with almost incredible force. Sand tamping, gently laid against it, is sufficient for dry holes, and water tamping serves for wet ones. Its extreme quickness in exploding makes it highly effective, even in blasting open, fissured, or potty ground, where ordinary blasting powder would be of little or no good. Dynamite has been proved to keep without any deterioration for years. If frozen, it is put in a warm place until softened fit for use. It is used in cartridges of oiled paper, or tin, each having a fuse with a cap fastened on one end, which penetrates the charge, and is secured in place by a string tied around the neck of the cartridge. At about 2*s.* per pound, in small quantities, it may seem to be expensive, but against this must be set its far greater strength and convenience than blasting powder, as well as its better adaptability for *small* bore-holes.

Nitrous oxide fumes from exploded nitro-glycerine have been complained of, but dynamite has acquired great favour in actual work on many parts of the Continent; and the risk of its exploding under any ordinary conditions, excepting those of actual work, is sufficiently remote to satisfy all reasonable requirements.

Another compound with which we have more recently been brought acquainted in this country is *lithofracteur*, first brought out under that expressive name in Germany, by Professor Engels of Cologne. According to accounts, it consists of 75 per cent. of nitro-glycerine, and the rest gun-cotton, constituents of gunpowder, and infusorial earth. Lithofracteur is a black plastic substance, manufactured (under trade secrets) so that it may be made up into cartridges of any sizes. It is employed much like dynamite, and offers similar advantages regarding tamping, &c. Fired by a capped or percussion fuse, it gives out immense force, otherwise there appears to be practically no liability of explosion. For some time past, it has been used in Germany with good results, and lately it has been submitted to the most searching tests upon its strength and safety at quarries near Shrewsbury, owned by Mr. R S. France, the results being very convincing of its value. The encouragement given by that gentleman to the carrying out of the experiments—no cost being spared to make them conclusive—deserves to be acknowledged in high terms.

The chief difference between dynamite and lithofracteur appears to be that the latter contains a small percentage of explosive ingredients besides nitro-glycerine, and therefore it may be expected to be somewhat stronger, which is some advantage, providing no element of safety be thereby sacrificed.

Since nitro-glycerine happens to enter into the composition of such explosive mixtures as those referred to, we are at present prohibited in this country from benefiting by the advantages accruing from their use. On the Continent their application is not hampered by any Nitro-glycerine Act, but their superiority, compared with powder, is taken advantage of daily. In this country the mining portion of the community is not prone to agitation, but every day adds to the dissatisfaction felt towards the Act alluded to, and the anxiety to witness proper modification thereof is already very great.

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